LOPPING REGIMES IN COMMUNITY-MANAGED SAL (*SHOREA ROBUSTA*) FORESTS OF NEPAL: PROSPECTS FOR MULTIPLE-PRODUCT SILVICULTURE FOR COMMUNITY FORESTRY

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

By
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2001

ABSTRACT

Lopping regimes in community-managed sal (*Shorea robusta*) forests of Nepal: prospects for multiple-product silviculture for community forestry

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Forest management decisions may contribute little to sustainable forest management if those decisions do not consider the interests of different socio-economic classes and ecological actions and reactions. Recently, an immense need has arisen for forestry to have multifaceted objectives i.e., to provide multiple products with due attention to environmental effects. This study explores the potentiality of managing sal (*Shorea robusta*) forests for multiple products. The research looked into two aspects - experimental and ethnographic. The experimental aspect involved lopping (0, 40, 60 and 80% lopping) and litter (with or without litter) treatments. The experiments were conducted in two community-managed sal forests in western Nepal, and examined treatment effects on stem growth (tree and plot level) and the regeneration of the forests.

One-event lopping up to 80% produced no adverse effects on diameter-at-breast-height (dbh), height, basal area or volume growth in two experimental forests in one year following the lopping, except the mean dbh and volume of dominant (tallest) trees and the mean volume of non-sal trees in younger and denser forest. Dominant (tallest) trees sustained up to 60% lopping but non-sal trees only 40% lopping before growth reductions. In contrast, lopping (40% and 60%) increased the growth in some instances in younger and denser forest. Litter removal produced no adverse effect on the growth.

The main effects and the interaction between lopping and litter removal did not adversely affect regeneration in either forest, but increased the frequency of regeneration in most of the cases.

The ethnographic study involved understanding the extent of the use of sal forests, and the indigenous knowledge of forest use and ethnosilviculture among users of three sal forests.

Nine-hundred and sixty-five statements (each statement makes a piece or block of information) from 111 key informants formed the basis of information.

The ethnographic study identified 637 uses and 328 blocks of ethnosilvicultural information. The relationships between indigenous knowledge status and socio-economic status (gender, age, ethnicity, income, and landholding) of respondents were analysed. Analyses showed a significant association at various levels, between types of information and socio-economic status; however, all socio-economic groups of the users held some sort of knowledge relating to forest management.

Based on a one-event lopping, experimental study has shown the possibility of lopping in producing foliage and litter from sal forests without adversely affecting the growth of the tree. The importance of lopped foliage and litter has been highlighted by ethnographic study. Furthermore, ethnographic study indicated importance of several other products from sal forests for various socio-economic groups. Devaluing any product in forest management may lower the interest of particular groups within the community. Excluding any group in management decisions will lower the effectiveness of management practices. The practical importance of this research and future research needs are discussed.

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Any errors or mistakes in this thesis are purely my own.

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CHAPTER I. INTRODUCTION

1.1 Rationale

The Brundtland Commission, based upon scientific evidence, concluded that the concept of sustainable development must be incorporated into resource management strategies (WCED, 1991); this conclusion was globally acknowledged at the United Nations Conference on the Environment and Development in 1992 (UNCED, 1994). The concept of sustainable forest management embraces multiple functions of forest for meeting diverse interests. The past resource management paradigm has been inadequate to deal with multiple functions and scales, and the Earth Summit declared forest management principles indicating the importance of multiple objectives/products of forest management (UNCED, 1994:105):

> Forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural and spiritual human needs of present and future generations. These needs are for forest products and services, such as wood and wood products, water, food, fodder, medicine, fuel, shelter, employment, recreation, habitats for wildlife, landscape diversity, and other forest products...

Forest management decisions became multifaceted, while considering the interest of different socio-economic classes and ecological actions and reactions. Considering sustainable multifaceted forestry, community involvement in forest management has become a major form of forestry in many parts of the world during recent decades (Gilmour and Fisher, 1997). Such forestry cannot achieve meaningful results for different groups by government's efforts alone. Decentralization and devolution became advanced in forest management, which mainly focused on the empowerment of local people to manage forests (Fisher, 1999). The importance of decentralization and devolution is reflected in the following extract from UNCED (1994:105):

> Governments should promote and provide opportunities for the participation of interested parties, including local communities and indigenous people, industries, labour, non-governmental organizations and individuals, forest dwellers and women, in the development, implementation and planning of national forest policies.

The evolution of forestry, in creating opportunities for the participation of interested parties, has changed the values of existing stands, and forest management must address such changed values related to each component of multiple products and multiple stakeholders. Obtaining multiple products from a piece of forestland necessitates the application of ecosystem management. The concept of ecosystem management attempts to involve all stakeholders in defining sustainable alternatives for the interactions of people and the environment (Galindo-Leal and Bunnell, 1995). It is based on a collaboratively developed vision of desired future ecosystem conditions that integrates ecological, economic, and social factors affecting an area that is defined by multiple boundaries including ecological and political ones. It is a goal-driven approach for restoring and sustaining healthy ecosystems and their functions and values while supporting communities and their economic base.

Forest management has the implicit objective of working for the good of the forest as an entity, not necessarily as an end in itself, but as a means of ensuring that it will be a permanently productive source of goods and benefits, which is ultimately in the best interests of society (Devoe, 1994). Silvicultural systems, however, were developed for industrial forestry, mainly for timber production (Baker, 1934; Champion and Griffith, 1948; Troup, 1952; Champion and Seth, 1968; Kayastha, 1985; Troup, 1986; Smith *et al.*, 1997). Although silviculture is applied ecology combined with economics (Devoe, 1996), it is usually practised to maximize immediate economic benefits. Most silvicultural operations are directed at the creation and maintenance of the kind of forest that best fulfills the owner's objectives, which are almost only timber in the case of industrial forestry. In most instances, products other than timber were not considered. Recently, however, non-timber forest products (NTFPs) have received attention, mainly extraction and marketing aspects, with the objective of enhancing commercial extraction. The implementation and/or expansion of commercial extraction of NTFPs as a conservation strategy seems to be promising in tropical forests (Ros-Tonen *et al.*, 1995), but if intensive resource extraction is the only activity planned for NTFP development, there is a high probability that these resources will be depleted over time (Peters, 1994).

Management of NTFPs has been a neglected field in tropical silviculture (Wood and Vanclay, 1995). The outlook for the sustainability of NTFP-based natural forest management, if left solely to market forces, is poor (Richards, 1993). The structure of tropical forest communities with respect to NTFPs is largely unknown. One of the main assumptions made in projecting the degradation of NTFPs in tropical forests is that harvesting damages these products (Peters, 1994). Harvesting and all silvicultural operations performed for the growth of a particular tree/species affect in one way or another the growth of all kinds of NTFPs. Thus there is still a gap in knowledge and skill regarding the management of timber and NTFPs from the same forest, and there is a need for a study focusing on increasing productivity through silviculture that is sustainable and protects biodiversity (O'Hara *et al.*, 1994). Community forest users are badly in need of information on productive methods of managing forests for non-timber forest products (Fox, 1995). Silviculturists are expected to contribute to realizing the continually changing values from existing stands (Oliver and Larson, 1996).

Developing any silvicultural regime must consider the changed values of forest management. Forest management norms must determine the appropriate use of a fixed area of land in order to receive the most efficient and equitable production of benefits and services for a diverse population. An appropriate landuse decision is based upon the knowledge of the returns -

social, environmental, political and economic - that result from planned activities. Thus, forestry's scientific dimension is leading to a much wider variety of forest-people interactions than was in conventional forestry, and forestry science can also be benefited from the knowledge of indigenous forest management systems (Wiersom, 1999). Exploration of such knowledge may be obtained with the involvement of local communities. UNCED (1994:107-108) has clearly guided:

> Appropriate indigenous capacity and local knowledge regarding the conservation and sustainable development of forests should, through institutional and financial support, and in collaboration with the people in local communities concerned, be recognised, respected, recorded, developed (compensated) and, as appropriate, introduced in the implementation of programmes.

Although very little is currently documented or known about the forms of resource management or economic strategies practised by populations dependent upon NTFPs (Anderson and Ioris, 1992), there is no vacuum of indigenous knowledge regarding the management of community forests for timber and non-timber forest products. Numerous studies on forest management have sketched the historical evidence of indigenous forest management systems (Posey *et al.*, 1984; Posey, 1985; Gautam, 1988; Fisher, 1989; Gilmour, 1989; Gomez-Pompa and Kaus, 1990; Messerschmidt, 1990; Fisher, 1991; Gautam, 1991; Shepherd, 1991; Bartlett and Malla, 1992; Messerschmidt and Hammett, 1993; Madge, 1995; Benecke, 1996; Posey, 1997; Messerschmidt and Hammett, 1998). These studies demonstrate that many traditional forest dwellers practice ecosystem management, producing many products such as wood, protein, starches, building materials, medicines, dyes, fodder, etc, from various phases of forest development. Systems are being documented in the Neotropics (Prance and Kallunki, 1984; Posey, 1985; Posey and Balee, 1989; Posey, 1997), indicating enormous knowledge among the users of multiple forest products.

On top of the forest products identified by outside professionals, users are using numerous other products from their forests. Besides products for direct use, forests have been providing inputs into the farming system. In Nepal, livestock (seven million cattle, three million buffalo, six million goats, 0.6 million sheep, 0.06 million yak, and other small animals) husbandry plays a major role in this system (BPP, 1995). Tree leaves constitutes a high proportion of fodder fed to animals, and litter (green and dry) is used as bedding material in animal sheds; both of these eventually contribute to fertilising agricultural land (Panday, 1982; Mahat, 1987; Gilmour and Fisher, 1991). HMG (1989) estimated that 2.7 million tonnes (42% of the total consumption of fodder of 6.39 million tonnes) of total digestible nutrients were supplied from forests; this amount, i.e., 2.7 million tonnes of digestible nutrients, is equivalent to 18.9 million tonnes of leaf fodder (Katila, 1995). In a study of eight forest users groups in western Nepal, all groups reported using forests for their fodder (up to 70%) and litter (up to 100%) requirements

(Chhetri, 1993). Traditional practices of lopping, browsing and litter collection in sal forests are reported from Nepal and elsewhere (Dinerstein, 1979; Agrawal *et al.*, 1986; Prasad and Pandey, 1987a; Chopra and Chatterjee, 1990; Pandey and Yadama, 1990; Mukhopadhyay, 1991; Upadhyay, 1992; Saxena *et al.*, 1993; Sundriyal *et al.*, 1994; Bahuguna and Hilaluddin, 1995; Bhat and Rawat, 1995; Nepal and Weber, 1995; Banerjee and Mishra, 1996; Rao and Singh, 1996; Melkania and Ramnarayan, 1998).

Practitioners and users have devoted increasing attention to the productivity of forests in terms of both timber and NTFPs, which can only be achieved through silviculture appropriate in a given social and cultural context. Indigenous knowledge could be the basis for exploring appropriate silviculture for a particular forest type in its socio-cultural context, as most of the forests under local management are natural forests. Although enormous qualitative knowledge exists, there is limited indigenous knowledge from which to expand quantitative management for the full range of products from these forests. Such management is important and relevant to the growing community forestry movement. It is clearly indicated that exploration of local knowledge of forest resources use and management is essential for developing any silvicultural regime to achieve sustainable forest management. To a larger extent, indigenous knowledge reveals location-specific information. The present study was based in Nepal, and so the contextual background relating to the forests and forestry of Nepal is relevant.

1.2 Background

1.2.1 Forest resources of Nepal

Forests of Nepal extend over tropical, subtropical, temperate and alpine regions. On the basis of species composition, Nepali forests are further divided, and Stainton (1972) identified ten forest sub-types in the tropical and subtropical forests, eleven broad-leaved and eight conifer forest types in temperate and alpine zones, and six in the minor temperate and alpine associations. Jackson (1994) classified the vegetation mainly on the basis of elevation: tropical- up to 1000 m; subtropical- 1000-2000 m; lower temperate- 2000-2700 m; upper temperate- 2700-3100 m; sub-alpine- 3100-4200 m and alpine- 4200-4500 m. The proportions of forest species types on the 6.3 million hectares of forested land and shrublands that existed in 1985-86 are given in Table 1.1.

Botanical authorities for this thesis are based upon the previous studies (Howland and Howland, 1984; Polunin and Stainton, 1984; Stainton, 1988; Storrs and Storrs, 1990; Gurung, 1991; Shrestha, 1998) unless specific references are cited. The latest authority is followed when the authorities conflicted with each other.

Table 1.1: Proportion of forest area covered by major species
(Adapted from HMG, 1989)

Broad type	Species type	% of the forest land
Conifer (14.2%)	Blue pine (*Pinus wallichiana*)	1.3
	Blue pine + fir (*Abies spp.*)	1.4
	Chir pine (*P. roxburghii*)	6.4
	Fir	2.2
	Fir + blue pine	0.9
	Fir + hemlock (*Tsuga spp.*)	1.3
	Hemlock	0.2
	Hemlock + fir	0.5
Hardwoods (53.3%)	Birch (*Betula spp.*)	0.3
	Deciduous mixed broadleaves (DMB)*	13.4
	Khair (*Acacia catechu*) -sissoo (*Dalbergia sissoo*)	
	Sal (*Shorea robusta*)	1.0
	Tropical mixed hardwoods (TMH)**	16.2 22.4
Mixed (18.4%)	Birch + fir	0.5
	Blue pine + DMB	0.5
	Chir pine + sal	1.5
	Chir pine + TMH	3.2
	DMB + blue pine	0.2
	DMB + fir	0.6
	DMB + hemlock	2.0
	Fir + birch	1.2
	Fir + DMB	2.0
	Hemlock + DMB	1.5
	Sal + chir pine	1.6
	TMH + chir pine	3.6
Unclassified (3%)	Conifer, broadleaves or mixed	3.0
Others (11.1 %)	Shrubs, plantation or burnt forest	11.1

* Species include *Terminalia, Anogeissus, Ehretia, Flacourtia, Lannea,* etc.
** Species include *Schima, Castanopsis, Alnus,* etc.

A recent nation-wide inventory showed that sal accounts for 28.2% of total stem volume of the country, out of 229 tree species listed in the inventory (HMG, 1999). Other major species contributing to total stem volume were *Quercus* species (9.3%), *Terminalia alata* (7.6%), and *Pinus roxburghii* (6.3%). On the basis of elevational classes, 68.8% of total stem volume was recorded in the forests located below 1500 m, which is the elevational zone of sal and other broad-leaved species. So sal forest, which extends from tropical to subtropical regions, is an important forest type in Nepal.

The forestry sector masterplan (HMG, 1989) categorized forests on the basis of accessibility; forests within a distance of three and four kilometers from villages were categorized as accessible in hill and Tarai regions, respectively. One-third of the total forest area was recorded as accessible for fuelwood and over two-thirds for fodder. A recent inventory (HMG, 1999) categorized forest accessibility as reachable and non-reachable; forests located on or surrounded by steep (over 100%) slopes or other physical obstacles were categorized as non-reachable. Forests inside the protected areas (national parks, wildlife reserves) were also included in non-reachable. Under this classification, 51.5% of Nepal's forests were found reachable. Criteria set by both of these studies may fit for fuelwood and fodder, but do not fit for assessing the accessibility of forests in Nepal; all forests of Nepal are used in some ways for timber and non-timber forest products (Researcher's own observations). The relationships between forests and their use cannot be linearly predicted.

Historical evidence (Gautam, 1991) showed four distinct stakeholders on the basis of forest management objectives in different geophysical locations of Nepal - Tarai, Mahabharat, Kathmandu valley and surroundings, and hill regions. The first three regions had always been influenced by the interest of ruling elite whereas forests of hill regions were of local concerns mostly. Gautam and Devoe (1998) documented the history of forest policy in Nepal into five periods - issue-specific (pre-1950s), externally influenced (1950-77), internally developed (1977-1988) and comprehensive (1988 onwards). Current forest policy (HMG, 1993a) divides the national forests into five classes for management purposes - government-managed forests, protected forests, community forests, leasehold forests, and religious forests. Private forests can only be developed and managed on private land (HMG, 1993a). The present study focuses on community forests, which has been the major focus of Nepal's forest policy since the 1970s.

Bajracharya (1983) modeled the relationships between forested land and human life sustenance in a Nepali village (Figure 1.1), and Gilmour and Fisher (1991) sketched similar results (Figure 1.2). The relationships between people and forest shown in these studies are still valid. However, forests have been improved after the initiation of community forestry.

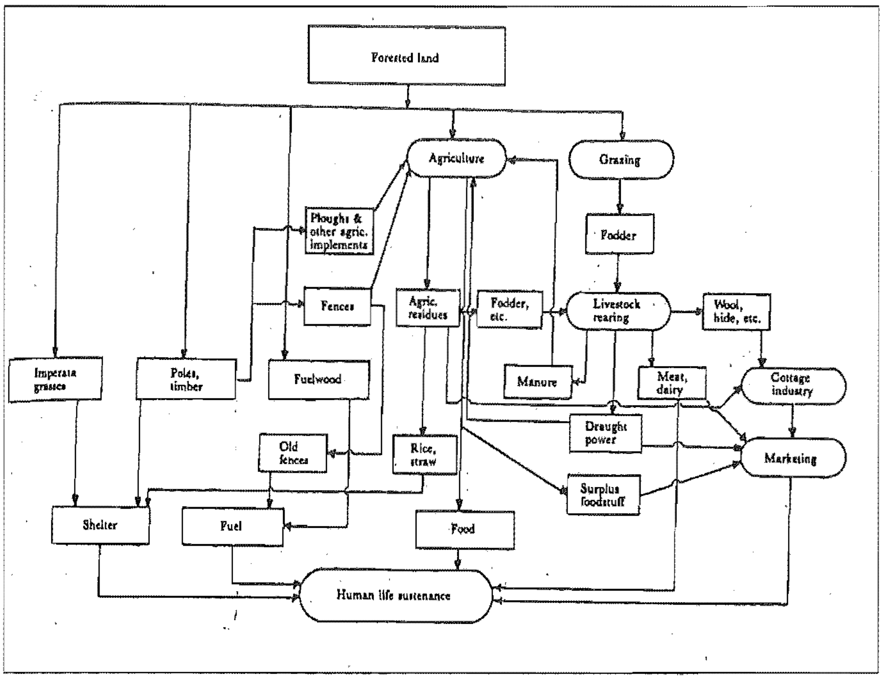

Figure 1.1: Model of the relationships between forested land and human life subsistence
(From Bajracharya, 1983, with permission)

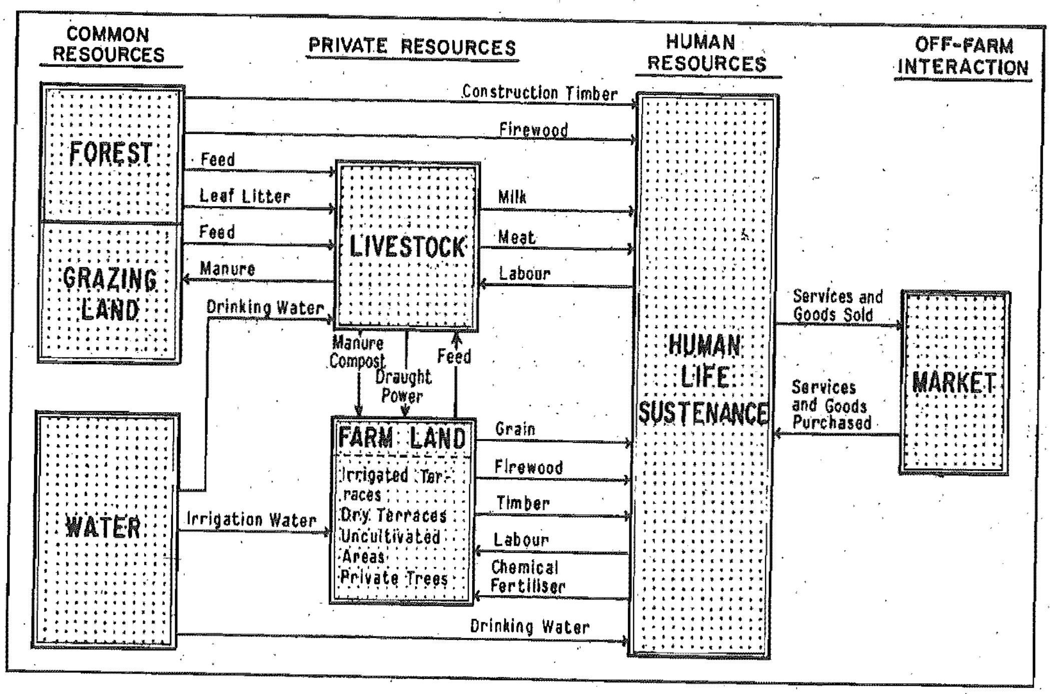

Figure 1.2: Interrelationships linking forests with agriculture and human subsistence in a typical middle hills agricultural area
(from Gilmour and Fisher, 1991, with permission)

1.2.2 Indigenous to community to indigenous forestry

The local system of forest management existed in Nepal since time immemorial (Griffin, 1988). The influence of industrial forestry in Nepal dates back to the early 1920s, but was focused only on extracting sal from Tarai forests for supplying timber to Indian railways. Enactment of Private Forest Nationalization legislation in the 1950s was the first influence of industrial forestry on the rest of the country's forests. This Act, unintentionally, eroded interests of local users in managing forests, and this period has thus left negative effects on the local system of forest management. Forests in the middle hills were reported as the country's most degraded in the late 1970s (Ekholm, 1975; Ekholm, 1976; HMG, 1977; HMG, 1989).

Forests offices were made functional in hill regions, Doti, Pokhara, Trishuli, Chautara and Dhankuta, only in 1961. Nepali foresters encountered two conflicting situations in the hills regions in 1960s, the existence of effectively protected forest patches scattered throughout the country in one end, and degraded forest at the other extreme. The latter situation could not be improved even after protection efforts from government. Evidence of the smooth functioning of indigenous forest management practices in scattered patches in the hills inspired the vision of community forestry for hill regions (Molnar, 1981; Gautam, 1988; Gautam, 1991). Three weeks of extensive discussions (1974) on issues of Nepali forest management among forestry-practitioners concluded stating the need for long-term planning in the broader forestry context

(Personal communications with many of the participants, and also see Gilmour and Fisher, 1991; Hobley *et al.*, 1996). Participation of local communities was seen as vital in the forestry plan[1] (HMG, 1977). Accordingly, community forestry programs were introduced in Nepal in the late 1970s to meet the subsistence needs of the rural population, particularly in the hills region. Subsequently forest legislation was amended creating provisions for community forestry development. Donors responded encouragingly to use the new avenue of community forestry development (HMG, 1978). 'Forests for people', the theme of the Eighth World Forestry Congress (1978), may have been a major contribution for attracting donor's commitment. Since then, community forestry has evolved and gained great momentum in Nepal. The masterplan for the forestry sector (HMG, 1989) named community and private forestry as the top priorities, and allocated 46.6% of total resources to them.

Community forestry programs have not been static but have evolved with implementation experiences over the last two decades. Evolving phases are clearly seen through the changing objectives, activities, nature and patterns of institution. In the 1970s, forestry extension included the material, message and approach to motivate people in forest protection and management, whereas these days people are approaching the forestry office to accept responsibility for forest management (Gautam, 1997a). Forest department, especially forest service, was considered responsible for forestry extension, but now several other agencies, such as NGOs/ INGOs, are also involved. Most effectively users groups are working themselves for community forestry extension (Gautam, 1999), and thus community forest is expanding exponentially. In fact, Nepal's community forestry development experiences have been an example and inspiration for community forestry development elsewhere (Poffenberger, 2000).

Community forestry programmes were initially designed for increasing forest products (mainly timber, fuelwood, fodder) for rural people through participation of rural people. Village *panchayats*, the smallest political/administrative units, were considered the appropriate unit for community forest management (Manandhar, 1982). Activities were directed towards local management through operational plans and their implementation, but remained as village-level afforestation schemes till the mid-1980s (Campbell and Bhattarai, 1983; Patar, 1984; Gautam and Roche, 1987; Griffin, 1988). Implementations of such plans were not encouraging; plans, however, created opportunities to understand the geographical relation between forest location and *panchayat*, and harnessing local knowledge and indigenous forest management practices (Gautam, 1987; Gautam, 1988; Gilmour, 1988). Implementation efforts sensitized local people to the legacy of their forests, as in many cases the forests managed under the indigenous system

[1] Burley (1994) stated that people's involvement in all aspects of forestry was stimulated by sociologists rather than foresters, but in Nepal it was foresters who first realized the need for people's participation while sociologists contributed heavily in the later stages.

were allocated to different groups located in other *panchayats* (Gautam, 1987; Gautam, 1993b). The reactions from the implementation experiences pressured the government to adopt a 'forest-users-group' instead of '*panchayat*', as an institution to manage community forests (HMG, 1989). The spirit of this policy was institutionalized by new forestry legislation (HMG, 1993a), and it was a major contribution to community forestry development (Kanel, 1993; Pardo, 1993). Bylaws (HMG, 1995) and guidelines (HMG, 1996) made further efforts towards strengthening forest users groups. Thus, only after 15 years' evolution following initiation of community forestry was an appropriate local institution for managing community forests identified. The evolution made it possible to return indigenously managed forest areas to respective indigenous users groups. However, many such groups were already damaged severely by the earlier efforts of tying *panchayat* boundaries with forestry resources, and many are still confused.

Handover of forests to the respective users began only in the early 1990s, after the new legislation was enacted. However, processes started immediately after the Forest Act (HMG, 1993a) was passed by Parliament in 1992, and operational plans were prepared. Although some forests were handed over to village *panchayats* prior to the new legislation, they were later revoked and handed over again to appropriate users. By end of 1998, 452 635 ha of forests were handed over to 6731 community forest users groups (CFUG) in Nepal (CPFD, 1998).

Community forestry activities remained plantation-based in the bare land around villages till the late 1980s; however, some existing forests were also handed over as *panchayat*-protected forests (Karmacharya, 1987). Management remained in protection of plantation and other forests handed to respective *panchayats*. Utilization was restricted to dead and dying trees, grass, and leaf litter. Most of the activities including protection were supported from development projects. The increasing costs of protection became the great concerns of the forestry sector (Gautam and Roche, 1987; Karmacharya and Fisher, 1987; Parajuli and Tuladhar, 1993).

Forest management activities, guided by operational plans, were implemented only after the forests were entrusted to users. Experiences of operational plan implementation led to various issues relating to seedling production (Epstein *et al.*, 1993), plantation establishment (Baral, 1993; Niraula, 1993), utilization (Paudyal and Aryal, 1993), and self-reliance on forest products (Chhetri *et al.*, 1993). Occurrences of conflicts of different natures (Kharel and Regmi, 1995; Pradhan-Malla, 1995; Shrestha, 1995a; Shrestha, 1995b; Siktel, 1995; Tumbahamphe and KC, 1995; Gautam and Shrestha, 1997; Paudel, 1997) also informed operational plans implementation. Based on encouraging results from community forestry development in the mid-hills region, prospects and constraints of community forestry beyond mid-hill region were also explored (Gautam, 1993a; Jackson *et al.*, 1993; Shrestha and Budhathoki, 1993; Baral and Subedi, 1999).

Community forest operational plans are still based on the principles developed for timber production. Although implementation of community forestry operational plans produced a few non-timber forest products and generated income for the users (Edwards, 1996; Gautam, 1997b; Messerschmidt and Hammett, 1998; Gautam and Devkota, 1999; Pokharel *et al.*, 1999; Pokharel, 2000), forest improvement activities are still focused more on timber production, neglecting the potentiality of other products. This is the conflict of value-judgement between forestry professionals and users. Conflicts regarding preference for forest products exist not only between central authorities and local communities, but are also prevalent within communities. More than one socio-economic group formed a CFUG in most instances. The emerging needs and interest of different stakeholders appeared as a serious issue of community forest management (Maharjan, 1998; Soussan *et al.*, 1998; Malla, 2000). Not meeting the concern of any one sector of the group led to the issue of equity, which has been the concern of community forestry since its initiation in the 1970s (Hobley, 1987; Hausler, 1993). Poor and disadvantaged groups experienced difficulties to wait and invest for timber-only production without intermittent product/income (Richards *et al.*, 1999). This has forced poor people to look for options to meet their needs, such as fuelwood, fodder and litter. In some cases, such people are leaving the group (Maharjan, 1998; Soussan *et al.*, 1998). Thus if forests are not producing the products needed by the local poor, they cannot be forced to participate in the forestry for the benefit of the elite group alone. Lanly (1989:1) wrote:

> "... forest can survive only if the land itself is seen by the people concerned to be more valuable retained as forest than converted to any other form of use. Future survival of the forests thus depends on their productive utilization, at the same time ensuring the conservation of genetic resources and the maintenance of the environmental functions such forests perform."

Eventually, the larger portion of the community forest users, being poor and disadvantaged, will be away from the mainstream of community forestry, and community forestry will be in the grips of local elite. Sustainability of community forestry is at risk.

Community forests should be managed for multiple products up to their productive potential in order to attain sustainability. Research directed to this field is urgently required to maintain the momentum of development of community forestry in Nepal. Researchers in the past were mostly assigned by the central authority to study subjects of interest to the government. Extensive research and exploration were undertaken to identify commercial species most contributing to revenue. Thus, despite the long history of use and practice, information on many of the indigenous species continues to be inadequate, especially for those that are of local importance only (Leslie, 1989). Foresters are supposed to support technical backup in managing community forestry (HMG, 1993a). Silvicultural operations, such as cleaning, singling, thinning and pruning are being prescribed by rule of thumb, as scientific study on such issues for many of Nepal's forests, particularly for community forestry, are still scanty (Condori, 1984; Fisher, 1990; Gilmour *et al.*, 1990; McCracken, 1992)]. Inadequate information created avenues for manipulations of forestry practices for elites' interest, and a few cases[2] of such disputes have affected the development of community forestry and are threatening the future of community forestry (Baral and Subedi, 1999). Learning of appropriate silviculture and management techniques for producing multiple-products from ecologically diverse environments is essential for sustainability of community forestry management (Branney and Dev, 1993; Pokharel *et al.*, 1993; Soussan *et al.*, 1998; Yadav and Branney, 1999). Focussing on production of multiple-products may dilute the equity issues that occurred due to dissatisfaction of some stakeholders. Efforts need to be directed to exploring appropriate silvicultural techniques for producing a variety of 'product mixes' from a particular forest; forests in the mid-hills require immediate actions with such techniques.

A significant portion of mid-and-lower-hill forests is now under the management of community forest users groups, and the trend toward community management is increasing. More than 90% (by number and area) of the community forests are in tropical and subtropical forests. Major forest types under users' group management are sal (*Shorea robusta)* and chilaune-katus (*Schima-Castanopsis)* forests, and these forests constitute 16 and 13 percent, respectively, of the country's forest cover (HMG, 1989). Out of the total forest handed-over as community forests in the country, 28.5% by area and 19.4% by CFUG number are sal forests (CPFD, 1998). Additionally 14.8% by area and 15.1% by CFUG number of handed-over forests are subtropical forests with sal dominance (ibid). Thus, 43.3% by area and 34.5% by CFUG number of community forests are sal forests. So, sal is a major forest type entrusted to forest users, and sal forest management is very important for the success of community forestry development.

1.2.3 Sal forests and multiple products

Sal occurs gregariously on the southern slopes of the Himalayas and is distributed in Bangladesh, India and Nepal (Figure 1.3). Its presence is indicated in Bhutan (Messerschmidt,

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[2] Insufficient technical guidelines have caused several instances of over-exploitation and forest abuses while implementing operational plans. Even without deviation from operational plan, two cases, one each in Tanahu and Lalitpur districts, reported abusing forests. Legal cases were filed against CFUG committee and the forests withdrawn. Forestry officials were also suspended for not monitoring well.

Pers. Com.) and South China (Fu, 1994; Zhao *et al.*, 1994), too. Broadly, sal's range lies between the longitudes of 75^0 and 95^0 E, and latitudes of 20^0 to 32^0 N. Within this range, the distribution is controlled firstly by climate and then by edaphic factors.

Sal forests are distributed on the plains and lower foothills of the Himalayas including the valleys. It penetrates through mid-mountain range (Mahabharat region) to the far north along river slopes and valleys. Sal forests cover about 110,000 ha in Bangladesh (Alam, 1996), 10 million hectares in India (Tewari, 1995) and one million hectares in Nepal (HMG, 1989). This forest type extends from a few meters to 1500 m above mean sea level.

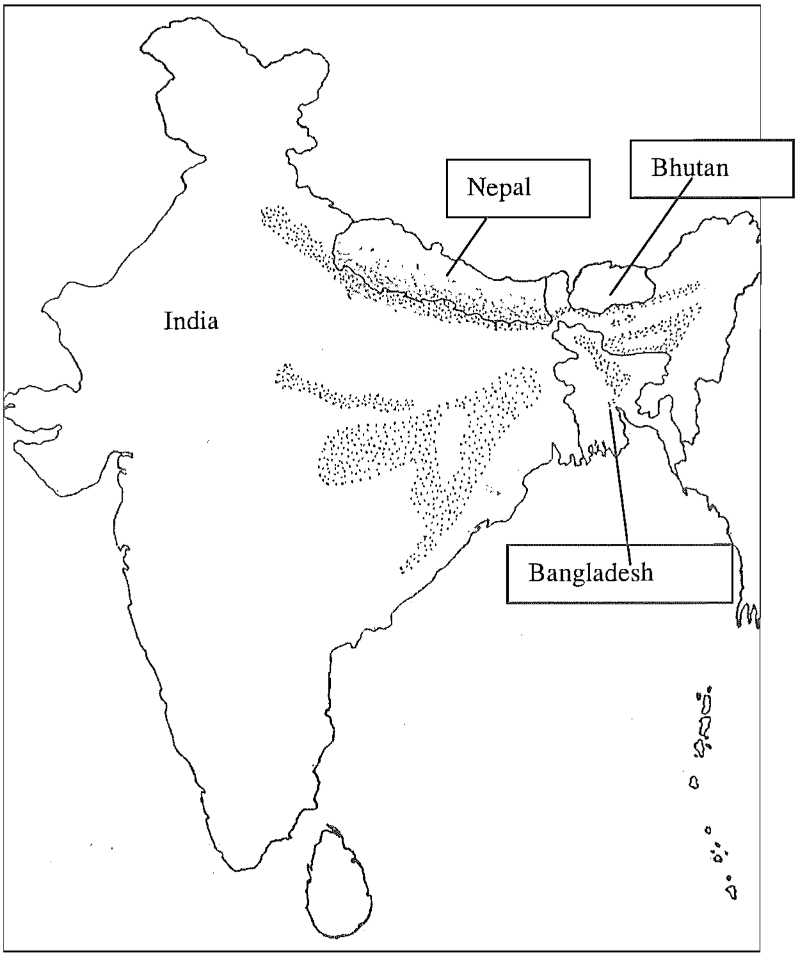

Figure 1.3: Natural zone of sal forests
(Shaded dots for sal forests, after Stainton, 1972; FAO, 1985)

Sal grows on a wide range of soil types, except in the very sandy, gravely soils immediately adjoining rivers and in waterlogged areas (Jackson, 1994). It can grow on alluvial to lateritic soils (Tewari, 1995), and prefers slightly acidic to neutral sandy loam (pH 5.1-6.8) with organic carbon content between 0.11-1.8% (Rana *et al.*, 1988; Gangopadhyay *et al.*, 1990).

Sal forests extend into the tropical and sub-tropical regions, and to the zones where precipitation ranges from 1000-2000 mm and above, and the dry period does not exceed four months (Tewari, 1995). Sal tolerates some frost, but annual heavy frosts occurring in frost hollows are detrimental to seedlings (Prasad and Pandey, 1987b). The maximum temperature recorded for sal forest is 49^0 C (Singh and Chaturvedi, 1983).

Broadly, the sal forests types are identified as dry sal, moist sal, coastal sal and wet sal (Champion and Osmaston, 1962). However, they can be separated into two extreme types, the dry and the wet; between these various gradations occur (Troup, 1986). These two types occur in a continuum from east to west; extreme wet sal forests are prevalent in the east and at the other extreme, dry in the west. Based on the associated species, the distinction between these two types of forests appears to be fine one (Stainton, 1972). However, Stainton (1972) classified the sal forests of Nepal into Bhabar and Tarai sal forest and Hill sal forest, and the situation outside Nepal does not contrast with this classification. Bhabar and Tarai sal grows to a considerable size, whereas in Hill sal much smaller trees are found. In a north-south line, Hill sal is drier than the Bhabar and Tarai sal.

Sal forest is seen by the government more as a timber source rather than for other forest products, and government manages sal forests mainly for timber. As sal forest extends to the most heavily populated zones, local people access sal forests for different uses, irrespective of whether they are designated as protective (Kumar *et al.*, 1994; Lehmkuhl, 1994; Bhat and Rawat, 1995; Aryal *et al.*, 1999) or productive forests (Nair, 1945; FRIB, 1947; Mathauda, 1958; Verma and Sharma, 1978; Rana *et al.*, 1988; Maithani *et al.*, 1989; Patnaik and Patnaik, 1991; Rajan, 1995; Tewari, 1995; Gupta *et al.*, 1996b; Ganeshaiah *et al.*, 1998; Melkania and Ramnarayan, 1998; Gautam and Devkota, 1999; Pokharel *et al.*, 1999; Pokharel, 2000). It is evident that sal forests have potential to yield other forest products, too. A sal tree in addition to timber and fuelwood, produces fodder (Panday, 1982; Gautam, 1990; Pandey and Yadama, 1990; Mathema, 1991b; Upadhyay, 1992; Thacker and Gautam, 1994; Fox, 1995; Shakya and Bhattarai, 1995; Edwards, 1996; Gautam and Devkota, 1999), leaves for plates (Rajan, 1995; Gautam and Devkota, 1999), seed for oil (Verma and Sharma, 1978; Sharma, 1981) and feed (Rai and Shukla, 1977; Sinha and Nath, 1982), resin or latex from heartwood (FRIB, 1947), and tanin and gum from bark (Narayanamurti and Das, 1951; Karnik and Sharma, 1968). Furthermore, associates of sal are known to produce edible fruits, fodder, fibers, leaves for umbrellas, medicinal plants, thatch, grass, broom, and many other products depending upon the species composition (Jolly, 1976; Gautam, 1990; Mathema, 1991b; Upadhyay, 1992; Bhatnagar and Hardaha, 1994; Chandra, 1994; Thacker and Gautam, 1994; Fox, 1995; Shakya and Bhattarai, 1995; Tewari, 1995; Edwards, 1996; Sah, 1996). Species compositions of sal forests indicate diverse NTFPs in sal forests, which are collected by subsistence users. These products are traded, too.

Dwivedi (1997) has detailed fodder (trees, shrubs and climbers) species in India, and many of them are present in sal forests. Two studies (Panday, 1982; Amatya, 1990) have listed fodder-tree species in different regions of Nepal, and about 40% of the listed species are found in sal forests. Sal forests have been used for fodder and litter in Nepal and elsewhere (Stainton, 1972; Chettri and Pandey, 1992; Schmidt *et al.*, 1993; Jackson, 1994; Tamrakar, 1994; Melkania and Ramnarayan, 1998).

In the past, sal forests were managed solely in the interests of the ruling elite. Accordingly, management norms were developed to maximize revenue. This took management decisions out of the hands of local people. Although history indicates little interest of the ruling elite in the forests of the hill regions of Nepal, their management guidelines influenced the management of these forests for timber alone. Management for elites and subsequent involvement of professionals since the mid-1950s resulted in the neglect of products other than timber from sal and species other than sal in species-rich sal forests. Eventually, tracts of sal forest in the Nepal hills containing only mature sal trees with no regeneration became frequent (Stainton, 1972). However, as reported earlier, sal forest has potential for producing many non-timber forest products, and the whole range of products from sal forest is still not known. Ecosystem-based management, i.e., "managing ecosystems in ways compatible with both ecological processes and people's needs" (Oliver and Larson, 1996:397), could be the best option for sal forests producing 'product mixes', as required for community forestry development. Detouring ecosystem-based management would be neglecting the forests for the majority of the users, and could threaten sustainable management of community-used/managed sal forests. Investigation of the range of products used by local people from sal forest will be the basis for exploration of ecosystem-based management; users are reliable sources for such information.

1.2.4 Sal silviculture

Sal is a light-demanding species, and complete overhead light is needed in most cases from the earliest stages of its development (Champion and Seth, 1968; Kayastha, 1985). Some side shade may be helpful under dry conditions, and young plants may require protection from frost and drought (Jackson, 1994; Tewari, 1995). Sal regenerates from root suckers and seed, and it coppices well. Opening of canopy in a forest stand promotes regeneration, and the growth of understorey seedlings and saplings (Troup, 1986; Gautam, 1990).

Efforts are continuing since the early 1900s in India to develop appropriate silvicultural systems for sal forest management. Most management so far described is focused on securing regeneration of sal (Hole, 1921; Troup, 1986; Tewari, 1995). Sal forests are being managed under both high forest and coppice systems (Champion and Griffith, 1948; Troup, 1952; Champion and Seth, 1968; Troup, 1986). Selection, clear felling and shelterwood systems are implemented under high forest systems. Simple coppice, coppice-with-standards, coppice-with-reserves and selection coppice are followed under coppice systems. Most of these efforts are building on judicious canopy opening (Tewari, 1995). Improvement felling and climber cutting are sometimes being prescribed for sal stand development. Most of these operations are favouring sal timber, except in a few instances where fruit trees and other species yielding valuable non-timber products are retained (Tewari, 1995). The major focus of the improvement felling is removing less valuable trees for the development of more valuable species. Coppice-with-reserves is practised in some sal forests in proximity of settlements, where high demand exists for poles, fuelwood, fodder and other small wood (ibid).

Sal forest rotations of 120-150 years are typically prescribed (Leslie, 1989). Throughout the rotation, although NTFPs are present, management is not directed toward them. On the contrary, many of NTFP-producing species are dealt with as weeds, and are cleaned in timber improvement operations (HMG, 1977). With timber production alone, benefits are accrued only at long intervals, a luxury poor people cannot afford. Thus, the people living close to these forests are little-interested in managing them. Conflicts occur in the types of forest products preferred by the manager and local people. Conflict between forest users and owners is common worldwide (Devoe, 1996). Conflicts are heightened in sal forests, because sal's value as timber overshadows the other products.

Sal forests are managed under high forest systems in different parts of India, mainly for timber production (Tewari, 1995); such systems give little consideration to the intermittent products. High forests systems, mainly selection, have been applied in Nepal's sal forests since the 1920s, but heavy grazing has hindered regeneration establishment. Coppice systems have also been implemented since the early 1900s in sal forests of India, and these systems are found appropriate for supplying small- and middle-sized timber, poles, fuel, fodder and grazing (ibid). Coppice-with-standard system is used both in pure and mixed sal forests in the proximity of cultivation, and such forests are managed under rotation of 40 to 60 years for timber, fuelwood, fodder and grazing (Tewari, 1995). Coppice systems are not practised in government sal forests of Nepal, and only recently the systems are under trial in community-managed forests

(Tamrakar, 1994; Tamrakar and Danbury, 1997). The coppice systems allow managing forests with intermittent products (NTFPs including fodder and litter) while producing timber in the long-term.

Users' concerns in sal forest start from regeneration and early growth. Collection of green foliage for fodder is an established practice. Tamrakar (1994) recorded 85% of the foliar biomass from a sal forest as fodder. Sal leaf litter for animal-bedding and compost have been in use for centuries around sal forests; however, lopping has not yet been part of the formal silviculture for sal forests.

HMG (1995) has made provision for thinning, pruning, cleaning and other forest improvement activities for community forests. The objectives underlying such silvicultural operations are three-fold - supply of intermittent products, creation of an avenue for inter-cropping and hygienic operations for the main crop, i.e. sal trees. It has clearly spelled out that such actions should not be harmful to the growth of trees. However, no scientific information is available on lopping regime for managing community forests. Community forest users are deprived of benefits through lack of the scientific basis for silvicultural operations in general and lopping in particular. In this context, research on the effects of removing foliage will have meaningful results for community forest management.

1.2.5 Lopping regime

Lopping is very common for fodder trees. Depending upon the species and age of tree, fodder is collected by lopping branches or de-leafing (Panday, 1982). Normally young trees are lopped very cautiously, i.e., not affecting their growth, whereas mature trees are lopped by removing some branches. Most fodder trees are lopped completely, but a few species are lopped leaving some leading branches (Amatya, 1990). Trees located on public land are haphazardly lopped whereas trees on private land are lopped more systematically (Panday, 1982; Mathema, 1991a). Trees of *Quercus semecarpifolia* located in private and government forests have been lopped differently (Mathema, 1991a).

Lopping events in sal forests (government forest) of Nepal and elsewhere have been documented (Stainton, 1972; Dinerstein, 1979; Malhotra *et al.*, 1990; Agrawal *et al.*, 1991; Jackson, 1994; Sundriyal *et al.*, 1994; Bahuguna and Hilaluddin, 1995; Bhat and Rawat, 1995; Jashimuddin *et al.*, 1999; Rawat and Bhainsora, 1999). Most of the forest protection activities in sal forests are initiated in response to degradation by heavy and haphazard lopping, and immediate actions have been to control lopping. Protection activities followed by management as community forests have resulted in dense young forest stands. People who are dependent for their subsistence needs upon these forests are looking for products such as fodder and litter from them. In the absence of a lopping regime in formal silviculture of sal forests, the products are not regulated. Due to high demand, some community forest operational plans allow grazing, and lopping of some species (mainly non-timber species and other locally defined inferior species) is regulated (personal observations).

1.3 Research objectives

Of the several products that people are using from sal forests, this study focuses on the use of foliage (green and dead). The questions posed in this research relate to whether removal of foliage from tree /forest results in detrimental effects on residual forest growth and regeneration. It is important to identify the maximum intensity of lopping that a tree/forest can sustain, as lopping of lower foliage provides fodder and fuelwood to the majority of community forest users. Besides fodder, fuelwood and litter, forest policy (HMG, 1993a; HMG, 1995) encourages production of other NTFPs in community forests without reducing the density and growth of trees. Lopping may affect the understorey environment and eventually the flora and biodiversity, which constitute important products for community forest users.

The broad objective of the research was to contribute to the development of appropriate silviculture for multiple-product, timber and NTFP (plant products), management of community forests in Nepal. In order to enhance the development of appropriate silviculture for multiple products, the prime objective of this research was to:

i. identify the effects of tree lopping and ground litter removal on stem growth and regeneration of plant species.

In a silvicultural regime that aims to diversify forest products without affecting tree growth in locally managed forests, indigenous knowledge about the NTFPs is important. Accordingly the other objective of the study was to:

ii. investigate the availability and indigenous knowledge of NTFPs in sal forest.

The study, within the framework of these objectives, aimed at contributing to understanding the ecological functioning of NTFPs in the management of tropical forest in general, and management of multiple products in sal forest in Nepal in particular.

Achieving the above-set objectives requires long-term research, which may involve multi-event treatments. Due to time and other constraints, this study encompasses only one lopping event and its immediate effects. However, understanding the immediate effects of a single lopping and litter-removal event may be important to community forest management. In the absence of long-term results, lopping and litter-removal could be applied to community forest management in cycle, by dividing the forest into several sub-compartments or coupes depending upon the indication of immediate effects. Lopping cycle will have to be investigated for different types of forests, as lopping only once will not be a practical application for community forest management (community forests are relatively small in size, i.e., area).

1.4 Hypotheses

Two main hypotheses were tested in this work to examine the immediate effects of a single lopping and litter removal event:

1. one lopping event up to 80% of tree height would produce no adverse effect on

    i) stem growth, and

    ii) regeneration of sal forests;

2. litter removal would produce no adverse effect on

    i) stem growth, and

    ii) regeneration of sal forests;

Moreover, the study explored a hypothesis "sal forest produces multiple-products" and tested the following hypotheses on indigenous knowledge:

i) local people have indigenous knowledge of multiple-products (availability, use and ethnosilviculture) from sal forests; and

ii) the poor section of the community holds more indigenous knowledge of multiple products than wealthier sections of the community.

'Poor' in this study was used to represent the weaker section (socially and economically) of the community. The emphasis was on 'the last' of the 'first-last' dichotomy as depicted by Chambers (1983). Although many of the characteristics of 'the first' and 'the last' (ibid) were very relevant for the study sites, this study relied upon the users' assessments in determining the poorest of the poor in the respective group. Users' judgements were mainly based upon ethnicity/caste, occupation, landholding and elitism. Gender and age were stratified in each social group.

1.5 Thesis structure

This thesis is presented in nine chapters. Following this introduction, the conceptual and theoretical aspect of the research is explained in Chapter Two. Detailed methodology covering site selection, including site descriptions, to data analysis is presented in Chapter Three. Baseline information from the forest stands is presented in Chapter Four. Chapters Five through Seven treat results - Chapters Five and Six present the results from experimental plots on growth and regeneration census, respectively; Chapter Seven covers indigenous knowledge of timber and NTFP management using information from ethnographic study. Discussions and overviews from the findings form Chapter Eight, and conclusion and recommendations are summarized in Chapter Nine. Additional information is in appendices.

CHAPTER II. CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1 Concepts: linking experimentation to ethnographic research

The research has two basic interwoven concepts:

- Indigenous knowledge systems and scientific knowledge systems are complementary. Issues can be identified from the indigenous knowledge system to focus scientific research. The strength of observations of indigenous knowledge systems can be combined with experimental methods (DeWalt, 1994). The results of scientific knowledge systems must ultimately be incorporated into indigenous knowledge systems.

- To make the research fruitful in managing community forests, the simple extraction of indigenous knowledge would have less meaning than research based upon empowering users. Participatory research is a powerful methodology for empowering forest users, and it encompasses the belief that experimental research can be conducted with the participation of the local community.

The study consisted of two major aspects: an ethnographic study, and experimentation. Hence the study had two main sources of information - the local people and an experiment. Accordingly, research methods were drawn from a diversity of disciplines that were appropriate to the research questions relating to the management of community forests. Posey *et al.* (1984) suggested a cooperative strategy for the formulation of development planning based upon a combination of indigenous ethnoecological knowledge and Western scientific knowledge.

Research followed the participatory approach, helping to foster complementarity between indigenous knowledge systems and scientific understanding. Methodologies for participatory research were developed mostly from on-farm research, and agroforestry research has contributed significantly to participatory methodologies (AFS, 1991). Participatory methodologies in other areas of forestry research are scanty, but are evolving within participatory forestry programs (Griffin, 1991; Rist, 1991; May and Pastuk, 1996; Sattaur, 1998; Becker, 1999; Urquizo, 1999). Under these methods, local people (in this study, the forest users) were full participants in the study rather than being merely objects of study, and they participated in the design of the present research. By the time the study was completed, the users had full knowledge of the findings (empowered with scientific knowledge). Theories from ethnoscience and forest management principles were drawn upon to address the issues identified for the study.

2.2 Phenomena of sociological context and their links to silviculture

Classes or groups, based on social, economic and special interests, exist in all communities or societies (Wolf, 1950; Olson, 1971; Slaughter, 1975). The importance of forest product varies with social class, and the importance evolves with changes in socio-economic and environmental conditions (Falconer, 1993; Black and Sessay, 1997; Bishop, 1998). With increasing economic development, wealthier people are less-dependent upon NTFPs, whereas NTFPs remain crucial to the poor (Falconer, 1993; Maikhuri *et al.*, 1994; Emerton, 1997; Perez, 1997). Socio-economic stratification led to classes with conflicting demands for forest products (McKercher, 1992; Schneemann, 1995; Daniggelis, 1997; Ramnath, 1997; Ankarfjard, 1998). Forest management decisions (policy, program, and legislation) were influenced by powerful classes (Mahat, 1985; Gautam, 1991; Sivaramakrishnan, 1995; Ghosh, 1998). No consideration of the management of forest products for the weaker sections of the community existed (Woon and Lim, 1996; Daniggelis, 1997; Ganjanapan, 1998). Thus, management decisions conflicted with the needs of the majority of the community, and eventually forest management decisions favoured the production of timber. Gadgil and Guha (1993:147) expressed this situation in India:

> It was the emergence of timber as an important commodity that led to a qualitative change in pattern of harvesting and utilization of forests. Thus when the colonial state asserted control over woodland earlier controlled by local communities, and proceeded to work these forests for commercial timber production, it represented an intervention in the day-to-day life of the Indian villagers which was unprecedented in its scope. Second, the colonial state radically redefined property rights, imposing on the forest a system of management and control whose priorities sharply conflicted with earlier systems of local use and control.

NTFPs became neglected, and remained the products of the weaker section (Daniggelis, 1997; Makungwa, 1997). Later, some NTFPs were seen as revenue-earning, and entered into the interests of the powerful, but confined only to extraction. Whenever the new products were found to be economic, they became inaccessible to the weaker section (Gautam and Devoe, 1998). This eventually gave the message to the local people that slowly all the forest's benefits were being transferred to the elite group, which then motivated the weaker section of the community to exploit forests before access was lost. The weaker sections of the community were thus forced towards adopting "extralegal" exploitation. This led to the creation of a forest-enemy group, representing the majority of the community (Wily, 1997; Ganjanapan, 1998).

As the majority of the local people became enemies of the forests, forests were rapidly degraded (Ekholm, 1975; Khooster, 1999). Degradation was further accelerated with the implementation of timber-favouring programs. The government's attempts to check the degradation exacerbated rather than reversed the forests-in-crisis situation. As the government intensified forest protection activities, the results became more disastrous (Brouwer, 1993; Ganjanapan, 1998). It became clear that mere government policy and programs could not check the degradation.

On the other hand, scattered small patches of forest around the hills regions of Nepal (Molnar, 1981; Gautam, 1987; Gautam, 1988; Fisher, 1989; Gilmour, 1989; Gautam, 1991; Mansberger, 1991; Chettri and Pandey, 1992; Dahal, 1994) and elsewhere (Gadgil and Vartak, 1975; Rathakette *et al.*, 1985; Saint-Pierre, 1991; Shepherd, 1991; Lebbie and Guries, 1995; Sinha, 1995; Singh *et al.*, 1996; Debal *et al.*, 1997; Decher, 1997; Khan *et al.*, 1997; Nair *et al.*, 1997; Ofoumon, 1997; Parthasarathy and Karthikeyan, 1997; Singh, 1997; Chandrasekhara and Sankar, 1998; Maikhuri *et al.*, 1998; Pandey, 1998; Tiwari *et al.*, 1998; Decher and Bahian, 1999) were effectively protected without any input from the government. Such evidence led to understanding that people's participation in protecting the forest resources was vital.

Nepal's forest policy pioneered in stating the importance of people's participation for sustainable forest management (HMG, 1977). Community forestry development activities evolved for the last two decade (see 1.2.2). However, the management long remained protection only, i.e., passive management (Poffenberger, 1996). Users expressed discomfort with such management, and sought active management (personal observations in various parts of Nepal, and especially in Sindhupalchok district, also see Gautam and Nirala, 1994; Gautam, 1995; Gautam *et al.*, 1995; Gautam and Devkota, 1996).

Active management of community forests involves management of forest for all members of the community, and eventually for the production of multiple products, timber and non-timber forest products. Unless the forest is believed to be the source of forest products for every member of the community, participation cannot be expected (Geores, 1998). Users indicated their interest in increasing production from their forests in quality and quantity. Thus, evolution of community forestry is leading to management of forests for multiple products, with active local participation.

The CFUG's interest led to multiple-product forest management, and it demanded appropriate silviculture for the specific forests entrusted to the respective CFUGs (Danbury and Bowen, 1993; Lal, 1996). Techniques for management of NTFPs were lacking. NTFPs for subsistence use were simply extracted but not managed. Users/professionals/practitioners felt that it was necessary to develop appropriate silviculture to produce timber and non-timber forest products from community forests. To begin this process, capturing indigenous knowledge was of prime importance (Messerschmidt and Hammett, 1993). It necessitated identifying the groups within communities that were directly involved with forestry activities.

NTFP extraction, except a few cases (Padoch and Pinedo-Vasquez, 1996) of industrially produced products such as rubber, rattan and nuts, is generally different from timber extraction. A few of the differences between extraction of NTFPs (for subsistence use and income) and timber are:

- NTFP extraction involves a relatively larger area than timber extraction;
- NTFP extraction may extend throughout the year, but timber is normally extracted only a certain time of the year, e.g. from late autumn to mid-spring in Nepal;
- Most of the NTFPs' production (quantity and quality) fluctuates spatially and temporally, and only local people will have first-hand knowledge of such fluctuations;
- Normally NTFPs are not collected on a full-time basis, but are collected while engaging in other activities in the forests;
- Most of the income-aimed NTFPs are collected when farm or other work is not available.

Thus, NTFPs extraction usually involves engaging local people, whereas a crew hired from elsewhere can extract timber. People involved in such extraction constitute the weaker section of the community (Falconer, 1993; Saastamoinen, 1998); they are either self-motivated to earn their living or are engaged as paid labour (Poffenberger, 1996). NTFPs provide opportunities for earning cash, especially at times when other means of earning fail, and eventually the weaker section of the community have stronger ties to the forest than other sectors (Falconer, 1996).

NTFP gatherers, who normally sell unprocessed material because they need money immediately, acquire knowledge (location, abundance and phenology of NTFP species) from observation in the forests (Hyman, 1996). Due to lack of capital and techniques, gathers are not normally involved in processing and marketing. Wealthier people, who can invest and afford to take risks, are mostly involved in processing and marketing (Hyman, 1996). Wealthier people normally do not go to the forests (they have better options of involving themselves, i.e., trading as middle-persons, processing or marketing), so the people who do go to the forest pass on their knowledge to the wealthier. The wealthier-group's knowledge of the silviculture of the particular forest may be better than that of outsiders (non-residents) but not as good as that of the poorer section. The quest for knowledge of multiple-product forest management could be aided by testing the hypothesis that the poor section of the community holds a larger portion of ethnosilvicultural knowledge.

Sociological phenomena evolved in the forest management are summarised in Figure 2.1.

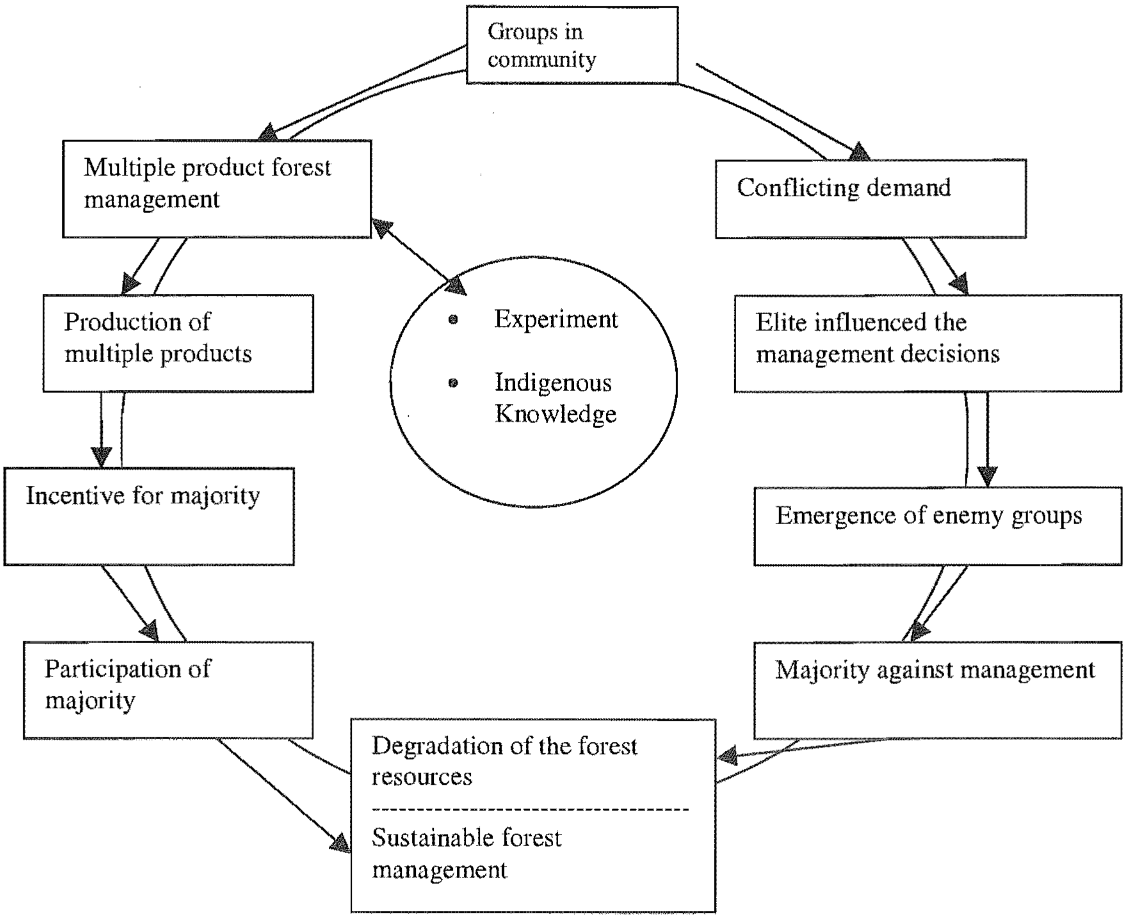

Figure 2.1: Sociological phenomena of forest management

The importance of NTFPs for the majority of the developing countries' populations has been spelled out since the last few decades, but these products have not featured prominently in forest management (Falconer, 1996). NTFPs are part of forest ecosystems, and are affected by silvicultural operations (Saastamoinen, 1998). Silvicultural practices that neglected the importance of NTFPs for people living near forests led to the disappearance of locally valued products (Falconer, 1996). Thus, to attain sustainable forest management in the future, forest management norms need to be modified to meet the demands of all classes of the community in general and the majority of the people in particular. The present situation requires a stronger ecological orientation of forest production (Spellmann, 1992). Upgrading productivity through the application of appropriate silviculture is a challenge for sustainable management of community forests. As the products from a forest ecosystem are numerous, they cannot be grouped into one management category. Achieving multiple-products production from forest ecosystems is an immediate challenge for forest management (Falconer, 1996; Saastamoinen, 1998). Opportunities and constraints of the present challenge are to be explored through an experimental silvicultural regime.

2.3 Silvicultural perspective

Silviculture is a scientific art of producing desired forest products through the application of silvics, which deals with the biological principles of growth and development of trees and forest stands (Franklin *et al.*, 1997; Smith *et al.*, 1997). Silviculture depends on the ability to carry out favourable disturbances in forest stands and predict the results (Smith, 1992). Silviculture can thus achieve social objectives by producing forest products within biological limits. Silvicultural actions create conditions favouring the production of certain forest products (Molina *et al.*, 1997), and the actions vary with the species, and their composition (pure or mixed) in the forest stand. Pure stands have trees of one species whereas mixed stands comprise of more than one tree species (Smith *et al.*, 1997). This study deals with sal-dominated mixed-species forests.

2.3.1 Mixed-species forest

Natural forests typically form mixed-species stands, and they show a stratified height structure with differences in phenology and root structure (Kelty, 1992; Larson, 1992). These characteristics enlarge the opportunity for managing forests for multiple products. Knowledge to exploit these opportunities is essential for designing silvicultural systems (Lavigne, 1992). However, guiding principles for the management of mixed forest are inadequate (Spellmann, 1992), and thus challenges lie in developing such principles from species interaction characteristics.

In the mixed-species forest, interaction between species is usually competitive. However, two categories of species interactions - complementarity and facilitation - enhance forest production and have been described as "basic" (Vandermeer, 1989; FAO, 1992; Kelty, 1992; Kelty and Cameron, 1995).

Complementarity

Complementarity in plant communities relates to coexistence in mixtures, and is understood as "good ecological combining ability" (Harper, 1977: 265). Plants are complementary when their interaction is mutually beneficial. Complementarity between species could be either temporal or spatial or both. Functional attributes of plants that can lead to complementarity in resource capture include root and canopy architecture and phenology. The present study focuses on above-ground aspects only.

Canopy stratification results in a spatial separation of light interception among species. The main factors causing canopy stratification are differences among species in terminal height, height growth trajectories, and leaf area density (Kira *et al.*, 1969; Lowman, 1986; Fajvan and Seymour, 1993; Oliver and Larson, 1996). Phenological differences can cause temporal separation of canopy. A combination of sparsely foliated species in the upper canopy with densely foliated lower-canopy species or a deciduous upper canopy above an evergreen lower canopy may maintain both species in the mixture even if the density of the taller species is rather high. Also the mixture of shade-intolerant and shade-tolerant trees optimises the resources so far as complementarity of crown interactions is concerned. Species mixed on a tree-by-tree basis promote the development of a stratified canopy, which eventually maximizes interspecific interactions (Kelty and Cameron, 1995).

Facilitation

Facilitation is taken as positive interactions in plant communities (Callaway and Walker, 1997; Hilmgren *et al.*, 1998). Facilitation is seen either in increasing production through increased nutrient availability or in reducing loss of tissue through protection mechanisms mainly from pests and wind. Nutrient availability is normally maintained by increasing litter decomposition rates, and fixing atmospheric nitrogen through symbiotic association. Shade reduces loss of moisture through high insulation and protects susceptible species or individuals from desiccation. Most facilitating factors are from below-ground interactions, but the present study is focused only on above-ground interactions.

2.3.2 Silviculture for multiple products

Single layer to multiple layers

As silviculture is the manipulation of forest stands, silvicultural operations can be described as either making the stand's growing space available to desirable species and individuals, or putting these species in a competitively advantageous position (Oliver and Larson, 1996). Silvicultural practices are, therefore, deliberate disturbances to a forest stand in order to produce the desired product. The disturbances are ultimately the application of the foresters' knowledge of stand dynamics. Exploring various manipulations to achieve the expected results in practice has resulted in knowledge of stand development (Larson, 1992). Modern silvicultural theories and practices, which were initially developed largely from artificially regenerated forests, concentrated mainly on single-species stands, and were later developed for the management of mixed-species stands (Kelty *et al.*, 1992).

The productivity of mixed forests has been a concern for decades especially in tropical forest management (Kelty *et al.*, 1992). Smith (1992) discussed the layered canopies in mixed-species forest, and the underlying growth patterns and interactions of individual trees in mixed-stands, i.e., stand development processes of mixed-species forest stands. Studies have shown that species' differences in height, form, efficiency and duration of photosynthesis, or phenology could result in mixed-species forests outyielding single-species forests (Ellem *et al.*, 1970; Trenbath and Harper, 1973; Kelty, 1992), though this is not always valid (DeBell *et al.*, 1989). Most of these silvicultural studies have concentrated on wood production, mainly timber, and so are directed towards the growth of the dominants and co-dominants of the stands. Even within dominant and co-dominant layers, studies dealing with interactions in combination of more than two species are rare (Kelty, 1992), whereas non-timber forest products are present, normally, in different layers of forests. This reflects the lack of appreciation for multiple-product production in mixed-species forests within existing silvicultural systems.

Major gaps exist in the knowledge of species interactions in the production of multiple products from mixed-species forest stands. Multiple-product forestry requires a silvicultural system that maximises the combined growth of understory and overstorey, and involves an understanding of complementarity (reducing competition) and facilitation in the forest stand. Light and soil resources are two main areas of interaction where complementarity and facilitation can be introduced in mixed-species forests.

One way of optimising complementarity in mixed-species forest stands is to make more use of available light. Changing the canopy structure of any stand may lead to increased light-use efficiency and total light interception (Kelty, 1992). Canopy structure can be changed either by thinning, or removal (partial or full) of foliage, or both. Thinning may result in too much light for shade-tolerant species. Manipulating the canopy through foliage removal may increase light in the lower layers, also ensuring the growth of understory species that grow best in partial shade. A study focusing on response to foliage manipulation is relevant to multiple product forest management, as there is a lack of full knowledge of the silvicular characteristics of many understory species. Furthermore, foliage is a prime product in sal forest and effects of manipulation of the foliage on other ecosystem components are largely unknown.

2.3.3 Foliage and growth

Leaves are the principal photosynthetic compartments of woody plants. Carbohydrates, water and mineral nutrients are supplied to and transported from the leaves through veins that thoroughly permeate the mesophyll tissues (Kozlowski and Pallardy, 1997). Besides changes in photosynthesis, a change in foliage may lead to changes in ground temperature, which eventually changes the nutrient status through changes in the litter decomposition process. Any changes in the foliage will eventually influence (positively or negatively) the growth and development of individual plants, neighbouring plants, and the environment. These changes vary with species, site, and position. In the forest community, changes in the area and density of foliage will affect the light interception of the forest stand.

The position of the leaves at different light levels results in differences in acclimation characteristics, and results in a vertical gradient from leaves in the sun to shade (Kelty, 1992). No single species has high acclimation efficiency at both extremes of light intensity (Boardman, 1977). Generally leaves near the top of the canopy have higher rates of photosynthesis and become saturated at higher light intensities than those near the bottom of the canopy. Such differences are correlated with progressive decreases in stomatal conductance and mesophyll photosynthetic capacity from the top to the bottom of the canopy. Sun-adapted species are efficient at using direct sunlight whereas shade species are more efficient at using light at lower intensities, i.e., beneath other individuals (Trenbath, 1981; Vandermeer, 1989). Photo-bleaching may maximise carbon gain for low-light-adapted organisms. Although CO_2 concentration, temperature, and humidity differ with canopy height, the largest differences by far are found in the light intensity regime (Jarvis *et al.*, 1976). It is thus indicated that sun and shade adaptions deal mostly with foliage-level characteristics (Kelty, 1992). The rate of photosynthesis typically is much higher in leaves in the outer crown than in those in the inner crown (Kozlowski and Pallardy, 1997).

2.3.4 Senescence and abscission

Senescence is a physiological phenomenon that leads to death of an organism or some part of it, and senescence exists in all plants and at all stages of the life cycle (Woolhouse, 1978). The process involves the orderly dismantling of the components of plant parts retaining only those components that are needed and can be mobilised (retranslocation) to other plant parts and the immobile nutrients. It may be an efficient process of nutrient transfer from an old to a new generation. Among the plant parts, foliage senescence is easily noticeable, and starts with the breaking down of chlorophyll. The phenomena of leaf senescence vary with species, and other factors such as age, crown position and nutrient contents (Ghosh and Biswas, 1993; Negi and Singh, 1993; Ackerly, 1999).

Abscission denotes an active physiological process of shedding of plant parts, and it involves dissolution of cell walls at the point of weakening (Sexton and Woolhouse, 1984). Plants have separation layers, which are limited to specific locations; the locations are known as abscission zones. Abscission zones vary with species (ibid).

Senescence and abscission phenomena are usually coupled, and sequences for these processes are interchangeable depending upon the species, plant parts and environment; however, the senescence process is a prerequisite or signal for abscission (Osborne, 1973). The lapse between initiation of senescence and abscission varies with species and environment (Sexton and Woolhouse, 1984). Senescence and abscission phenomena are very relevant to the cladoptosis character of species (Wilson *et al.*, 1998), and understanding of these characteristics is necessary for managing forests, especially when foliage is the main object of management.

2.3.5 Cladoptosis (self-pruning) to lopping

Photosynthesis is reduced in the shaded leaves in the lower part of the stem. When lower branches cannot photosynthesize enough to provide for their own stem and leaf respiration requirements, the branches become non-functional and do not contribute to growth of the main tree stem (Rangnekar *et al.*, 1969; Linder, 1985). Non-functional branches may need photosynthate from the main tree stem for respiration, and slowly die (Oliver and Larson, 1996). Self-pruning causes the base of the crowns to shift upwards when the stand approaches full leaf area, and the degree of such self-pruning varies appreciably among species (Cochrane and Ford, 1978; Kozlowski and Pallardy, 1997). Thus, pruning of shaded lower branches of trees in a forest stand may increase the tree growth by removing a photosynthate sink (Stein, 1955; Linder, 1985; Kozlowski *et al.*, 1991; Oliver and Larson, 1996).

Natural shedding of branches in many species has stimulated foresters to think about the silvicultural operation of removing lower branches. Pruning has been the subject of study and experimentation since the 1930s. Based on the many changes in the physiological and light environment of the forest community after manipulating foliage, the self-pruning characteristic has been considered an opportunity to manage for desired quality of products, i.e., clear boles. Accordingly, reduction of branches and foliage has been one of the established cultures in forestry and horticulture. Several terms, such as lopping, pruning, and delimbing in forestry, trimming in horticulture and clipping in range management are used for foliage manipulations. Lopping and pruning are being used synonymously in forestry to mean cutting branches from stems, as part of silvicultural operations. Although their meaning is not different, pruning is mostly used to mean cutting branches and foliage to improve the quality of timber, i.e., to make knot-free or clear boles. The products, i.e., twigs, leaves and branches from such cutting, are not valued much except in agroforestry, where pruning products are used for mulching. The term lopping is used mostly for cutting branches for by-products: for example, lopping foliage for fodder is commonly practised. Pruning is also used for shoot or root cutting, but lopping is used only for branches. Pruning mostly aims to reduce knots in the stem, whereas lopping is used to optimise the combination of by-products and main products. The term 'lopping' is preferred in the present study, because the products are an object of management. However, studies relating to pruning, delimbing, trimming and clipping are relevant to lopping.

2.3.6 Review of the effects of lopping

Lopping (including pruning, clipping, or any other actions of removing leaves) effects on tree growth have been the subjects of forestry research for at least the last six decades. Studies have been made on conifers (Barrett and Downs, 1943; Buchanan, 1944; Downs, 1944; Helmers, 1946; Luckhoff, 1949; Boggess, 1950; Young and Kramer, 1952; Bennett, 1955; Stein, 1955; Slabaugh, 1957; Moller, 1960; Staebler, 1963; Staebler, 1964; Eckstein, 1970; James *et al.*, 1970; Dakin, 1982; Mwihomeke, 1983; Kellomaki *et al.*, 1989; Langstrom *et al.*, 1990; Velazquez *et al.*, 1992; LoCho *et al.*, 1997; Kimball *et al.*, 1998; Koyama and Asai, 1998), and broad-leaves (Clark, 1955; Skilling, 1959; Bhimaya *et al.*, 1964; Deveaux, 1969; Bredenkamp *et al.*, 1980; Sharma and Gupta, 1981; Sharma *et al.*, 1991; Majid and Paudyal, 1992; Pokhriyal *et al.*, 1994; Uotila and Mustonen, 1994; Bhat *et al.*, 1995; Singh and Thompson, 1995; Tschaplinski and Blake, 1995; Gupta *et al.*, 1996a; Pinkard, 1997). All studies except two (Stein, 1955; Bhat *et al.*, 1995) were conducted in either plantations or pots. Lopping responses vary with species, age, stand density, and stand type (natural or plantation), reflecting the need to understand the physiological responses to lopping before it can be practised in forest management.

Effects of lopping have been studied on the basis of diameter increment (at different height positions), height, basal area, volume, and biomass growth (referenced below). Changes in dominance in any forest community, and taper factor of trees have also been considered as effects of lopping. Lopping effects on the chemical constituents of leaves (Sharma and Gupta, 1981; Singh, 1998; Verma and Mishra, 1998; Vaithiyanathan *et al.*, 1999) and fruit (Khan *et al.*, 1992; Chandra and Govind, 1995) have also been studied.

Conifers

Pruning of the lower 30 per cent of the number of living whorls was recommended based on the diameter and height growth during the first five-year period following pruning of *Pinus strobus* (Barrett and Downs, 1943; Downs, 1944; Keller, 1968). Light pruning (20-25% of live crown) stimulated height growth in *Pinus monticola* during the first three years following pruning, without significant adverse effects on diameter-at-breast-height growth (Buchanan, 1944; Helmers, 1946); however, 20% pruning increased diameter-at-breast height from the third year after pruning (Helmers, 1946). Removing only the lower one-fourth of the live crown of Ponderosa pine did not affect adversely diameter and height growth during the first five years following pruning (Mowat, 1947). Pruning up to half of the live crown (or 60% of tree height) of *Pinus ponderosa* and *P. jeffreyi* did not produce any deleterious effect on growth after ten to sixteen years of pruning (Gordon, 1959).

Immediate response to the removal of the lower two live branch whorls in 20-year-old *Pinus resinosa* (red pine) trees had no detrimental effect on radial growth, but removal of three live whorls decreased growth by 13% at the end of the first growing season (Stephens and Spurr, 1947). In another study of red pine, diameter and height growth of trees pruned to 50 per cent of tree height were not reduced after three (Ralston, 1953) and five years (Slabaugh, 1957) following pruning; however, trees pruned above this height were either dead or lost dominance.

In the case of *P. taeda*, lopping 65% (and more) of tree height reduced diameter increment at breast height and at 50% of tree height position; however, 80% lopping produced greater diameter increment at 80% of the height (Young and Kramer, 1952). The height growths were not significantly different among lopping intensities.

Pruning of 50 per cent of live crown in young slash pine resulted in a significant reduction in diameter growth, but had little effect on height growth (Boggess, 1950; Bennett, 1955). Lopping 35 per cent of live crown in older and 50% in younger plantations was detrimental for diameter growth in slash pine trees (Bennett, 1955). Repeated (at two-year intervals) pruning of 25% of tree height in six-year-old slash pine reduced diameter growth but was not significantly different from no pruning (Boggess, 1950).

Lopping the lower 25% of live crown of Douglas-fir trees in a 28-year-old natural stand increased 6.5% and 4.9% of diameter and height growth, respectively, over unlopped trees, following 13 years of pruning (Stein, 1955). However, Staebler (1963) did not find any significant difference in diameter-at-breast-height growth of Douglas-fir trees with one-third of tree height pruned. The main difference in these two cases was that the former study was conducted in a closed stand and the latter in open-grown trees. Different notions of lopping intensity (proportion of live crown versus tree height) also obscure comparison in these two studies. Eckstein (1970) found the greatest diameter and volume increment in 50% (tree height) pruned trees after 11 years of pruning in a 42-year-old Douglas-fir stand. Measurements over 15 years following pruning showed that pruning up to half tree height did not adversely affect growth of 20-year-old Douglas-fir second-growth (Finnis, 1953). On the contrary, the diameter increment at two-thirds of tree height was greater in one-third pruned trees than that of unpruned (Staebler, 1963).

Pruning of 50% of green crown did not appreciable depress growth in young (25-35 year-old) *Pinus sylvestris* (Scots pine) trees after four years of pruning (Vuokila, 1960). In an assessment following 11 years of pruning in an 11-year-old plantation of Scots pine, pruning of 50% of live crown resulted in the highest diameter and height growth among pruned and unpruned trees (Popov, 1982). Langstrom and Hellqvist (1991) concluded that pruning reduced diameter and volume growth, but their treatments (lopping from the top) were not comparable with the former studies. Only a treatment, i.e., 75% pruning from below (lower crown), of the latter study could be compared with the treatments of the former studies, and in such intensity (75% pruning) all studies indicated detrimental effects on growth. Uotila and Mustonen (1994) recorded significant growth reduction in a *Pinus sylvestris* stand following five years after one pruning event of 40% of live crown.

A 19-year-old stand of *Picea glehnii* was pruned (zero, 30, 55 and 80% leaves), and examinations over 14 growing seasons showed reductions in the diameter growth with increase in pruning intensity, but little effect on height growth (Koyama and Asai, 1998). The effects of diameter reductions remained significant only during the first two years after pruning (ibid).

Pruning reduced height and diameter growth in *Cryptomeria japonica*, and the reduction increased with increase in intensity of pruning following two years after pruning (Takeuchi and Hatiya, 1977); the effects decreased with increase in stand density. Over a four-year period after pruning 40 to 76% of live crown of *Cryptomeria japonica* with stand density 1850 stems ha^{-1}, the basal area growth was reduced by six per cent at 40% and 23% at 76% lopping (Dakin, 1982). On the contrary, lopping up to 70% did not reduce height, diameter-at-breast-height and volume increment in 20 years after lopping in an eight-year-old stand of *Cryptomeria japonica* (Wang *et al.*, 1980).

Pruning up to half of the tree height improved growth in a 14-year-old red cypress (*Chamaecyparis formosana*) plantation-stand when measured after five years of pruning (LoCho *et al.*, 1997).

Angiosperms

Fifty-percent pruned *Juglans nigra* trees had fastest diameter growth at breast height two years after pruning, and the increase over that of the unpruned trees was significant at the 5% level (Clark, 1955). The same study showed that diameter growth at higher position was faster of up to 75% pruned trees than that of the unpruned trees, and also 75% pruned trees had the fastest height growth. Falcioni and Buresti (1997) recorded no growth differences between trees pruned up to one-third and one-half of tree height in a study of *Juglans regia.* Jemeson (1963) showed that pruning of *Juglans regia* tree crown up to 75% did not reduce tree growth.

Bhat *et al.* (1995) found increased girth of trees following 50% pruning in a tropical forest stand, while pruning heavier than 50% reduced the growth. Pruning effects are documented for a few other species, too. One-event pruning (against a repeated event after two years) of 25% of tree height produced best results after three years of pruning among pruning intensities ranging 0-75% of tree height in a five-year old plantation of *Platanus occidentalis* trees (Abdullah and Ali, 1988). Diameter growth at breast height in a twenty-year-old yellow birch (*Betula alleghaniensis*) stand was increased by pruning to half of the tree height, assessed after 10 years of pruning (Skilling, 1959). Clipping increased growth rate of twig length following pruning of *Quercus coccifera* (Tsiouvaras *et al.*, 1986). Deveaux (1969) noted similar instances in a poplar (*Populus* species) stand.

Negligible effects of lopping were observed in *Eucalyptus grandis*, and recovery after removal of 50% live crown was rapid (Bredenkamp *et al.*, 1980). Pruning up to 50% of the green crown length of *Eucalyptus nitens* produced no changes in height or diameter increment during the two-year period after pruning (Pinkard and Breadle, 1998b). All pruning treatments reduced diameter growth of three-to-five-year-old *Acacia mangium* stands, but only pruning over 40% of crown significantly affected the diameter growth (Majid and Paudyal, 1992).

Lopping effects on *Shorea robusta* have rarely been studied (at least they are not available in accessible literature), but Stainton (1972) asserted that stunted, pole-like sal trees in open areas close to heavily populated areas were results of repeated lopping.

Lopping for fodder also produced mixed responses. Basal area increment of *Acacia nilotica* was reduced by lopping, but lopping one-third of the crown was not significantly different from no lopping measured one year after lopping; the reduction was greater in younger trees (Sharma *et al.*, 1991; Rawat, 1993). Bhimaya *et al.* (1964) recorded greatest diameter-at-breast-height and height growth with 100% (leaving leading shoot) annual lopping for three years in *Prosopis spicigera. Bauhinia purpurea* L. responded with significantly greater growth of biomass, height and diameter for the first four years of pruning (Gupta *et al.*, 1996a). Both at 50% and 75% lopping, the growth of tree height was significantly greater over no lopping; fifty-percent lopping produced far greater growth of diameter-at-breast-height than other treatments (ibid). In contrast, Pokhriyal *et al.* (1994) noted decrease of collar diameter with increase in repeated lopping intensities from zero to 75% in *Grewia optiva*. However, based on an analysis of fodder and fuelwood biomass production, branch regeneration, and tree growth, 75% lopping intensity was recommended for *Albizia amara* in a silvopastural system (Roy and Choubey, 1999).

Lopping effects varied with season of lopping. Winter lopping of *Prosopis cineraria* improved diameter and height growth better than spring and summer lopping (Sharma and Gupta, 1981; Kumar, 1999). Heavy lopping (all branches removed except the leading shoot) of an *Acacia tortilis* plantation in summer significantly reduced the diameter growth, but growth was not significantly affected by the same intensity of lopping in other seasons (Tewari, 1998). Leaf fodder in winter was very much more nutritive as compared to other seasons (Sharma and Gupta, 1981). Falcioni and Buresti (1997) found winter pruning of *Juglans regia* superior (for diameter increment) to autumn pruning.

Competition for crown position in the canopy is constantly taking place as well-stocked stands grow; lopping can change the pattern. The higher the intensity of lopping, the greater the dropping of trees in lower crown classes in a young Douglas-fir stand (Stein, 1955). Pruning up to 50% of live crown did not change the dominance in some pine (Luckhoff, 1949; Slabaugh, 1957) and eucalyptus species (Bredenkamp *et al.*, 1980; Pinkard and Breadle, 1998b; Pinkard and Breadle, 1998a).

The effect of lopping on stem taper has been assessed. Lopping reduced tapering in *Juglans nigra* (Clark, 1955), Douglas-fir (Staebler, 1963) and *Chamaecyparis formosana* (LoCho *et al.*, 1997).

While pruning effects on individual trees have been the subjects of study in forestry, studies of pruning effects on forest understoreys are still scanty. Pruning improved the growth of the existing regeneration of Douglas-fir (Eckstein, 1970). Depending upon the intensity, lopping increased mortality in conifer stands (Helmers, 1946; Slabaugh, 1957; Skilling, 1959).

Effects of lopping intensities from 20 to 80% (of tree height) have been examined. Only one study (Bhimaya *et al.*, 1964) mentioned 100% lopping leaving leading shoot alone, but it is not clear what the length of foliage was in the leading shoot. The following effects have been documented in response to lopping:

- Change in diameter growth at various stem height positions;
- Change in tree height growth;
- Change in tree volume growth;
- Change in tapering of tree bole;
- Change of dominance in the canopy;
- Change in biomass (fodder) production;
- Change in understory;
- Changes in ingrowth and mortality in a forest stand.

The effects of lopping depended upon various factors. Lopping was not always deleterious to growth of trees, but also improved the growth depending upon the species and lopping intensity. Lopping did not affect adversely height growth in any case, but increased it in many cases. However, lopping produced differential effects on dbh increment, which can be broadly categorised as negative, neutral or positive (Tables 2.1 through 2.3). Most of the cases of negative effects (Table 2.1) were immediate effects, which ranged up to six years; the six years' case had repeated lopping. Tables 2.2 and 2.3 present cases for which effects were measured over a longer period of lopping.

Only two broad-leaved species were affected adversely in dbh increment (Table 2.1), of which one had repeated lopping. Among the cases where lopping did not affect the dbh growth, species were both conifers and broad-leaves. Conifers with high intensity of lopping did not show effects after longer times following lopping. Most of the species that benefited from lopping in dbh growth were broad-leaved, only four conifers showed enhanced dbh growth. Of the four cases of conifers benefited by lopping, three were assessed after 11-13 years following lopping, and the two assessed within three-to-five years were lopped with low intensity. On the basis of reviewed cases, the optimum levels of lopping for broad-leaved species were higher than for conifers. The differential effects could be attributable to their leaf life spans (evergreen and deciduous), as most of the broad-leaved species reviewed are deciduous whereas the conifer species reviewed here are evergreen. However, such differential effects may not be always supported (Vanderklein and Reich, 1999).

Although not enough cases were reviewed to compare the effects of one-event lopping versus repeated-event lopping, the reviewed cases showed the relatively detrimental effects of repeated lopping.

Table 2.1: Cases of reduced dbh growth following lopping

Species	Stand	Age	Lopping intensity	Measured after years	# of lopping events	References
P. resinosa	Plantation	20	Three live whorls	1	One	(Stephens and Spurr, 1947)
P. taeda	Plantation	14	65% height	1	One	(Young and Kramer, 1952)
P. caribaea	Plantation	6	50% height	6	Repeated	(Boggess, 1950)
P. caribaea	Plantation	5-11	50% crown for younger and 35 for older	4		(Bennett, 1955)
P. sylvestris	Stand		40%	5	One	(Uotila and Mustonen, 1994)
P. glehnii	Stand	19	30-80%	2	One	(Koyama and Asai, 1998)
P. radiata	Plantation		20-60% crown	Twice yearly	Repeated	(Sutton, 1973; Sutton and Crowe, 1975)
Cryptomeria japonica	Dense		Any	2	One	(Takeuchi and Hatiya, 1977)
C. japonica	Stand		40-76%	4	One	(Dakin, 1982)
Acacia mangium	Stand		40%		One	(Majid and Paudyal, 1992)
Grewia optiva	Pot plants		Up to 75%	1	Repeated	(Pokhriyal *et al.*, 1994)

Table 2.2: Cases of no significant effects on dbh growth following lopping

Species	Stand	Age	Loping intensity	Measured after year	# of lopping events	References
P.monticola		young	20-25%	2	One	(Buchanan, 1944)
P.monticola		20-30	20-25%	3	One	(Helmers, 1946)
P. ponderosa		young	25%	5	One	(Mowat, 1947)
P. ponderosa *P. jeffreyi*			50%crown or 60% height	10-16	One	(Gordon, 1959)
P. resinosa	Plantation	20	Two live branch	1	One	(Stephens and Spurr, 1947)
P. resinosa			50%	3-5	One	(Ralston, 1953) (Slabaugh, 1957)
Pseudotsuga menziesii	Open trees		33%	1-2		Staebler (1963)
Pseudotsuga menziesii	Stand		50%	15		(Finnis, 1953)
Pinus sylvestris			50%	4		(Vuokila, 1960)
Cryptomeria japonica	Stand		70%	20		(Wang *et al.*, 1980)
Juglans regia			50%			(Falcioni and Buresti, 1997)
J. regia			75% crown			Jemeson (1963)
E. grandis			50%			(Bredenkamp *et al.*, 1980)
E. nitens	plantation		50%	1-2	One	(Pinkard and Breadle, 1998b).
A.nilotica			33%			(Sharma *et al.*, 1991; Rawat, 1993)

Table 2.3: Cases of increased dbh growth following lopping

Species	Stand/tree	Age	Lopping ntensity	Measured after year	# of lopping events	Reference
P. strobus			30%	5	One	(Barrett and Downs, 1943; Downs, 1944; Keller, 1968)
P. monticola			20%	3	One	(Helmers, 1946)
Pseudotsuga menziesii	Stand		25%	13	One	(Stein, 1955)
Pseudotsuga menziesii	Stand	42	50%	11	One	(Eckstein, 1970)
Pinus sylvestris	Plantation	11	50%	11		(Popov, 1982)
Juglans nigra			50%	2		(Clark, 1955)
Tropical forest stand			50%			(Bhat *et al.*, 1995)
Chamaecyparis formasana	Plantaton	14	50% height	5	One	(LoCho *et al.*, 1997)
Platanus occidentalis	Plantation	5	25%	3	One	(Abdullah and Ali, 1988)
Betula alleghaniensis	Stand	20	50%	10		(Skilling, 1959)
Quercus coccifera	Stand					(Tsiouvaras *et al.*, 1986)
Populus spp	Stand					Deveaux (1969)
Prosopis spicigera			100%	3	Repeated	(Bhimaya *et al.*, 1964)
Bauhinia purpurea				4		(Gupta *et al.*, 1996a).
Albizia amara			75%			(Roy and Choubey, 1999).

Furthermore, the review indicates that the following factors influence the effect of lopping within a species:

- Denser stands can withstand heavier lopping than sparser stands (Takeuchi and Hatiya, 1977; Kellomaki *et al.*, 1989). The lower foliage of trees growing in closed stands contributes less to the nutrition of the tree than does that of open-grown trees (Helmers, 1946). In a dense stand, lopping may change (improve) considerably the light environment of the lower crown of the lopped individual and also the lower canopies. Lopping coincident with canopy closure maximised the gain in tree growth (Pinkard, 1997; Pinkard and Breadle, 1998b). However, Gupta *et al.* (1996a) showed that *Bauhinia purpurea* trees planted at four metres spacing in a single row on a field-edge (indicating the tree crowns did not touch each other) resulted in significant increase in tree height and diameter-at-breast-height after four years of 50% lopping. The study did not include comparison among different stand densities.

- The best sites can withstand heavier lopping (Takahara, 1954; Pinkard and Breadle, 1998b). It may imply that fast-growing trees are least affected by the removal of leaves, as trees normally grow faster in best sites rather than other sites (Pinkard, 1997).

- Reich *et al.* (1993) and Pinkard (1998) found greater photosynthetic response to pruning in younger trees. Several studies suggested that younger plants respond more rapidly to defoliation or lopping than do older plants, and the response is more short-lived (Helms, 1964; Hodgkinson, 1974; Heichel and Turner, 1983; Pinkard *et al.*, 1998). Only two studies based on the same information (Sharma *et al.*, 1991; Rawat, 1993) have contradicted by concluding that lopping of an *Acacia nilotica* plantation was more detrimental to the growth of five-year-old than eight-year-old trees. The effects may have been due to other variations, such as density, crown-closure status and site quality, which were not spelled out.

- Winter rather than summer, spring or autumn lopping produced positive effects on tree growth as well as fodder quality (Sharma and Gupta, 1981; Falcioni and Buresti, 1997; Tewari, 1998).

2.3.7 Physiological and morphological mechanisms underlying the response to lopping

Most lopping studies have been confined to the growth of harvestable biomass and little is known about the physiological mechanism of lopping response (Kotwal, 1981; Sharma and Gupta, 1981; Tsiouvaras *et al.*, 1986; Singh and Thompson, 1995). A few efforts have been made to trace the physiological processes of lopping responses (Singh and Thompson, 1995; Kozlowski and Pallardy, 1997; Pinkard, 1997; Pinkard and Breadle, 1998b; Pinkard and Breadle, 1998c; Pinkard and Breadle, 1998a; Pinkard *et al.*, 1998; Pinkard *et al.*, 1999). The efforts are based on exploring the following response processes:

Plant water status;
Photosynthetic responses, i.e., CO_2 assimilation;
Net biomass production;
Dry matter partitioning.

Lopping changes leaf area and crown density, and reduces transpiration as an immediate response (Singh and Thompson, 1995; Teskey and Sheriff, 1996; Bandara *et al.*, 1999). As the relationship between leaf water potential and transpiration for woody plants is curvilinear (decreasing resistance with increasing flux), reduction in transpiration improves the plant water status for the remaining foliage (Wenkert, 1983; Myers, 1988; Kozlowski and Pallardy, 1997).

The physiological process relating to CO_2 assimilation following pruning is complicated and controversial, although photosynthetic enhancement after pruning is established (Sweet and Weiring, 1966; Hodgkinson, 1974; Caemmerer and Farquhar, 1984; Morrison and Reckie, 1995; Singh and Thompson, 1995). These processes are explained with reference to foliar N concentration, stomatal conductance, hormone concentration, biochemical reactions, light environment and sink-source relations.

Lopping resulted in an increase in foliar N concentration and enhanced photosynthetic activity in some species (Hoogesteger and Karlsson, 1992; Morrison and Reckie, 1995) but not in others (Lovett and Tobiessen, 1993; Reich *et al.*, 1993; Pinkard, 1997; Pinkard *et al.*, 1998). With a strong relationship between concentration of chlorophyll and N (Linder, 1980), observations of increased chlorophyll content after partial defoliation (Caemmerer and Farquhar, 1984) suggested the role of foliar N content in enhancing photosynthetic activity.

Improved plant water status increases stomatal or intercellular conductance and enhances photosynthesis (Hodgkinson, 1974; Wallace *et al.*, 1984; Blake and Tschaplinski, 1986; Reich *et al.*, 1993; Morrison and Reckie, 1995; Singh and Thompson, 1995). However, Pinkard and Breadle (1998b) and Pinkard *et al.* (1998) concluded on the basis of a study of lopping effects on *Eucalyptus nitens* that stomatal conductance may not be the sole factor influencing CO_2 assimilation.

Photosynthetic enhancement with lopping has been greater in younger trees (Reich *et al.*, 1993; Pinkard and Breadle, 1998c). The response has been relatively earlier and shorter in seedlings (Helms, 1964; Hodgkinson, 1974; Caemmerer and Farquhar, 1984; Pinkard *et al.*, 1998). The larger the plants, the more delayed was the response (Pinkard and Breadle, 1998c). This suggests that seedlings that have relatively low carbohydrate reserves respond more quickly than trees, which have relatively greater stored carbohydrates. The shorter duration of response in younger plants could be linked with the smaller storage capacity.

Heavily lopped trees enhanced photosynthesis relatively more quickly than lightly lopped in *Acer rubrum* (Heichel and Turner, 1983), *Pinus resinosa* (Reich *et al.*, 1993), *Alnus glutinosa* (Singh and Thompson, 1995), and *E. nitens* (Pinkard *et al.*, 1998). It is likely that severity of pruning increased the demand for assimilate from the remaining foliage (Pinkard *et al.*, 1998).

In most deciduous tree species, the total leaf area of a partially defoliated plant exceeded that of an undefoliated plant in the first year following defoliation (Nakano, 1977). Stimulation of leaf growth has been reported in response to partial defoliation in *Ceratopetalum apetalum* D. Don and *Diospyros melanoxylon* Roxb. (Kotwal, 1981; Lowman, 1982). Although the mechanism of transmitting sink demands to source is unclear (Pinkard and Breadle, 1998c), the instances above reveal that photosynthesis is influenced by the rate of translocation of photosynthetic products from sources to sinks. Lopping, as for other cultural practices, influences photosynthesis directly or indirectly by affecting some types of source-and-sink activities (Kozlowski and Pallardy, 1997).

Enhanced photosynthetic activity following source limitation in C_3 plants increased the rate of biochemical processes (Sharkey, 1985), a result later confirmed by an experiment with *E. nitens* (Pinkard and Breadle, 1998c). Biochemical processes increased carboxylation efficiency and RuBP regeneration capacity in response to source limitation following pruning (Hodgkinson, 1974; Caemmerer and Farquhar, 1984; Pinkard and Breadle, 1998c). Thus, it is most likely that enhancement of CO_2 assimilation following pruning relates to the rates of biochemical processes driven by sink demand (Pinkard and Breadle, 1998c).

Some species regulate CO_2 in response to environmental stress. This response increases the potential for maintaining a balance between assimilation and utilization of carbon, and ultimately minimising the impact of lopping on growth (Pinkard and Breadle, 1998c). However, there will be a level of source limitation at which photosynthesis is limited by the rate of one or more biochemical reactions such as increase in carboxylation and higher RuBP regeneration capacity, and above which complete compensation is not possible (Kozlowski and Pallardy, 1997; Pinkard and Breadle, 1998c). Beyond this threshold level, lopping may affect growth (Pinkard and Breadle, 1998c).

Physiological responses, such as increased CO_2 assimilation and changes in leaf area following partial defoliation, increased the net biomass of *Acer rubrum, Quercus rubra* (Heichel and Turner, 1983) and *Pinus resinosa* Ait. (Reich *et al.*, 1993). Similar results were obtained following lopping of *Alnus glutinosa* (Singh and Thompson, 1995), and *Eucalyptus nitens* (Pinkard *et al.*, 1999). Lopping, which removes both the sink (growing buds) and the source (leaves) of photosynthate, may have a different effect on physiological processes than defoliation, which removes only leaves. Besides changes in CO_2 assimilation and changes in leaf area, foliage distribution in the tree crown had a great effect on net biomass production following 50% pruning (Pinkard *et al.*, 1999).

Moderately lopped (56 % of leaves) *Alnus glutinosa* trees accumulated more dry matter than other more lightly or more heavily lopped plants between 60 and 90 days after lopping as a result of enhanced leaf growth (Singh and Thompson, 1995). Smaller amounts of dry matter accumulation in unlopped and lightly lopped plants might be the result of mutual leaf shading

(Verkaar, 1988), and as a result of limited leaf area development late in the growing season in heavily lopped plants (Singh and Thompson, 1995).

After pruning, plants partition more biomass to shoots at the expense of roots until a balance is restored between above- and below-ground biomass (Wareing and Patrick, 1975; Cannell and Dewar, 1994), and this partitioning favours leaf development (Caldwell *et al.*, 1981; Heichel and Turner, 1983; Gold and Caldwell, 1990; Hoogesteger and Karlsson, 1992; Pinkard and Breadle, 1998c). Heavily (80% leaf area removed) lopped plants had significantly higher shoot/root ratio than other lightly lopped and unlopped plants at 90 days after lopping, indicating that the lopped plant used more photosynthate on shoot growth (Fitzgerald and Hoddinott, 1983; Singh and Thompson, 1995). Stored root carbohydrates were translocated for shoot growth in the lopped plants (Parker and Houston, 1971; Wargo *et al.*, 1972; Detling *et al.*, 1979; Richard and Coldwell, 1985; Singh and Thompson, 1995).

Cannell (1985), while investigating partitioning of above-ground dry matter between wood and foliage, found a distinct trend of greater allocation of assimilates to wood with increase in total dry matter production among 204 broad-leaved and 303 coniferous stands. During the first year following pruning of *E. nitens*, 50% pruning increased the biomass partitioning to stem whereas 70% pruning decreased the partitioning to stem while increasing partitioning to leaves and branches (Pinkard and Breadle, 1998a). Both instances suggest that the more vigorous the tree, the higher the proportion of dry matter partitioned to the stem.

Partitioning between stems and branches depends upon the density of trees (Cannell, 1985). The proportion of above-ground woody increment taken by stems increased with increasing tree density in *Populus trichocarpa* (Cannell, 1980) and *Pinus radiata* (Madgwick, 1981).

Height growth is least affected by pruning as compared to diameter growth, as height growth depends upon carbohydrates and hormones produced in the upper crown (Kozlowski *et al.*, 1991). Growth hormone produced in the terminal buds moves down the stem, stimulating cambial activity (Avery *et al.*, 1937). Later, Young and Kramer (1952) similarly asserted that diameter increment at any given place on the lower part of the bole is primarily a function of the size of the crown above that place. This phenomenon could be a cause for the greater diameter growth at higher position (of tree height) following pruning as compared to unpruned trees, i.e., reduced tapering in pruned trees.

2.3.8 Lopping response mechanisms in forest stands

Although lopping does not change the light environment of dominant trees to a great extent, it does change the light intensity in the stand. Lopping facilitates light penetration to the lower layers of the stand by reducing the crown area and crown density. Effects of lopping depend on the stand density (Bull, 1943; Helmers, 1946; Takeuchi and Hatiya, 1977). Studies on the lopping response by different layers in a forest stand are rare; however, the following assertions can be drawn relating to mixed-species forest stands:

A tree in a forest stand has a significant ecological role. Different parts of the tree have different roles to play in the stand. "The leaves and branches cast shade, reduce the impact of rain and wind, moderate temperature extremes, and increase humidity for organisms in the understory and the soil" (Jones *et al.*, 1997:1946). The effects vary with life stages of the understory and the tree, and shade-and-drought-tolerance physiology of the understory (Callaway and Walker, 1997). Ground litter moderates raindrop impact, drainage, and heat and gas exchange in the soil habitat, and may create barriers or protection for seeds and seedlings from animals and microbes (Facelli and Pickett, 1991; Jones *et al.*, 1997). Any change in their (branch, leaf and litter) physical state can have both positive and negative ecological consequences for the local environment, ecological processes or the abiotic resources (light, water and nutrients). Besides the tree-level response, lopping of a tree in a forest stand changes the physical state of the forest canopy and ground litter.

Lopping reduces leaf area density, and this change may increase the diffuse fraction of light penetrating into the canopy (Kira *et al.*, 1969). The illumination declines exponentially with increasing depth and also depending upon the cumulative leaf area index from the top of the canopy (ibid). The relationships between relative light intensity and leaf area index vary with species; lopping of a forest stand increases light intensity in the lower canopies and understorys, depending upon the lopping intensity, density and height of the trees.

Lopping effects on understory growth vary with site conditions. In moist sites, the growth of the understory depends upon the availability of light. Increased light due to lopping promoted the growth of the understory in a Douglas-fir stand (Eckstein, 1970). In dry sites, where moisture is a limiting factor for growth, lopping reduces transpiration, and eventually the site may be improved due to retention of more moisture (Linder, 1985). This effect may prolong the growing period. However, lopping may encourage understory, increasing understory transpiration; canopy opening may result in soil surface evaporation. Lopping effects thus depend upon the local environment, and especially the litter environment of the forest stand.

Lopping changes the microenvironment (e.g., light, temperature, and humidity) in forest stands, and may affect regeneration. Increase in light at the forest ground has increased the survival of tree seedlings (Minkler and Jensen, 1959; Grubb, 1977; Augspurger, 1983; Augspurger, 1984).

However, the debris added by lopping may affect seedling densities negatively (Walker *et al.*, 1996). The effects vary with species (Everham *et al.*, 1996).

2.3.9 Nutrient cycling and litter effects

Nutrient cycling in a forest ecosystem is one of the principal processes that produces organic matter; it involves three phases - mineral uptake, retention (accumulation in biomass and translocation), and release (mainly leaf litter). Litterfall and decomposition are critical processes for transferring nutrients from forest biomass to soils (Vogt *et al.*, 1986). Maintenance of forest soil fertility is partly dependent on the return of N and other mineral nutrients through litter decomposition (Kozlowski and Pallardy, 1997). Nutrients from the litter will not be available to plants until microorganisms decompose the litter and release it (Gosz *et al.*, 1976; Nadelhoffer, 1983). Nutrient concentration and decomposition of litter vary with the species and plant organ; generally broad-leaved litter has a higher N concentration and decomposes more rapidly than conifer litter (Kozlowski and Pallardy, 1997). The chemical and physical nature of litter (leaf, bark, branch, and roots) affects decomposition and nutrient availability via controls on soil water and the soil fauna involved in litter breakdown (Rhoades, 1996).

Mineral nutrition appears to be an important factor in sal forest productivity. Litter is commonly collected in sal forests, which may affect nutrient cycling and status. Kaul *et al.* (1963) calculated the nutritional uptake of a 35-year-old sal stand, on the basis of samples collected from different parts of India. They calculated that nutrient requirements for all site qualities decreased in the order of Ca, N, K, P and Mg. The Ca requirement (by percentage of oven dry material) was determined to be 1.5 times that of N, two times that of K, five and seven times that of P and Mg, respectively. The study reflected that on better sites, or where the rate of stem timber production is greater, the nutrient requirements are much higher. On poor sites, nutrient status is lower, and a higher proportion of the uptake goes into the production of foliage.

Kaul *et al.* (1966) studied the effect of mineral (N, P, K, Ca, Mg, and S) deficiencies in sal seedlings, and showed that the deficiency of each of these nutrient elements except sulphur causes prominent symptoms (e.g. smaller leaves, thin tap root, premature defoliation, slow shoot growth) both on shoot and root. Deficiencies of N, P and Mg affected height growth. Deficiencies of Ca and Mg produced a shorter tap root and sparse distribution of lateral roots while N and K-deficient seedlings had thinner, longer tap roots. Seedlings without sulphur grew better than the ones with complete nutrients (N, P, K, Ca, Mg, and S).

Bhatnagar (1957) analysed the mineral contents (ash, CaO, MgO, N, K_2O, and P_2O_5) in sal foliage from different site quality classes, which were classified on the basis of top height at age 80 years (first quality being the tallest). First-quality trees showed the lowest concentration (per cent) of all minerals, whereas the lowest quality trees showed the highest percentage of N, P and K.

In a study of 21-year-old coppice sal forest, leaves contained the highest percentages of N, P, K, and Mg, while bark had the maximum percentage of Ca for all categories of trees, i.e., dominant, average and suppressed (Kaul *et al.*, 1979). The study calculated total nutrient content in a sal forest (Table 2.4); a comparison of leaf litter nutrients from different studies is presented in Table 2.5.

Table 2.4: Standing nutrient content of sal forest (kg ha^{-1})
(From Kaul *et al.*, 1979)

Plant part	N	P	K	Ca	Mg	Total
Leaves	59	6	18	40	7	130
Twigs	34	3	14	35	4	90
Branches	101	8	35	115	20	279
Bole	242	27	75	125	51	520
Bark	85	8	58	257	35	443
Total	521	52	200	572	117	1462

Table 2.5: Nutrients returned to the forest floor through leaf fall
(kg ha^{-1})

Nutrients					Authority
N	P	K	Ca	Mg	
59	2	23	57	18	(Singh *et al.*, 1993a)
72	4	23	83	13	(Pande and Sharma, 1988)
46	9	19	77	10	(Seth *et al.*, 1963)
59	6	18	40	7	(Kaul *et al.*, 1979)

The nutrients rates calculated in the four studies show little differences in the estimates of each nutrient (Table 2.5). The climate of measurement years, age of the forest, and methods of measurements may have contributed to these differences. One study (Kaul *et al.*, 1979) was in 21-year-old coppice forests whereas the others were older than 35 years when they were measured. Similarly, the destructive method (trees were felled) was followed in the case of the study by Kaul *et al.* (1979) while the others followed the litter-bag method (collected throughout the year in bags laid in the forest).

Litter production in sal forests ranged from 1010 to 6210 kg ha^{-1} year^{-1} depending upon the species composition and canopy cover (Misra, 1969; Pokhriyal *et al.*, 1987). Litter consists of leaves and twigs. Leaf litter decomposition is faster than twig decomposition (Pande and Sharma, 1993).

Maximum decomposition was in the rainy season, and turnover time to decompose the litter was 144 days (Munshi *et al.*, 1987). With the advent of rainfall in the last week of June, litter starts decomposing rapidly and by the time the next litter fall starts, most of it has decomposed and is incorporated into the soil (Misra, 1969).

Decomposition rate increased with increasing litter moisture and air temperature and decreased with increasing altitude and lignin content (Mehra and Singh, 1985; Upadhyay and Singh, 1986). After a period of one year, the loss of litter for sal was observed to be 56% of initial dry weight. Of the total decomposition, 40-45% of litter was lost from May to August due to higher temperatures and humidity (Singh and Ramakrishnan, 1982). Total loss had reached over 85% by 365-669 days depending on the site and species under study (Upadhyay, 1987). Transformation of green foliage was to litter and then to raw humus. It was observed that during the transformation (from green foliage to raw humus) some of the elements (Ca, Mg, K Na and P) were leached out while others (Si and Fe) accumulated (Gangopadhyay and Banerjee, 1987).

Pokhriyal (1988) studied the monthly changes in N content in canopy and litter, and calculated value for retranslocated N in the natural sal forest. Foliage nitrogen content in sal canopy was maximum (90 kg ha^{-1}) in January/February, and minimum (36 kg ha^{-1}) in April (Pokhriyal *et al.*, 1987; Pokhriyal, 1988; Pokhriyal *et al.*, 1988). Monthly N content (in percentages) in canopy, litter and storage parts (retranslocation) of sal foliage is shown in Figure 2.3. Leaf litter contributed the most nutrient return, release and accumulation. Sal trees translocate nutrients from the leaves prior to leaf fall (Sharma and Pande, 1989). Translocation of N to other parts is initiated once the canopy attains the highest point in January/February before leaf shedding starts. From January to April, canopy nitrogen is either translocated (0% in January to maximum 42.5% in April) to other parts or returned to the ground through litter (Pokhriyal *et al.*, 1987).

Pokhriyal *et al.* (1987) recorded a progressive increase in the nitrogen content of canopy foliage from the bottom to the top. The nutrient moves towards the upper canopy, and leaves in the lower canopy start the translocation process earlier (Pokhriyal *et al.*, 1988).

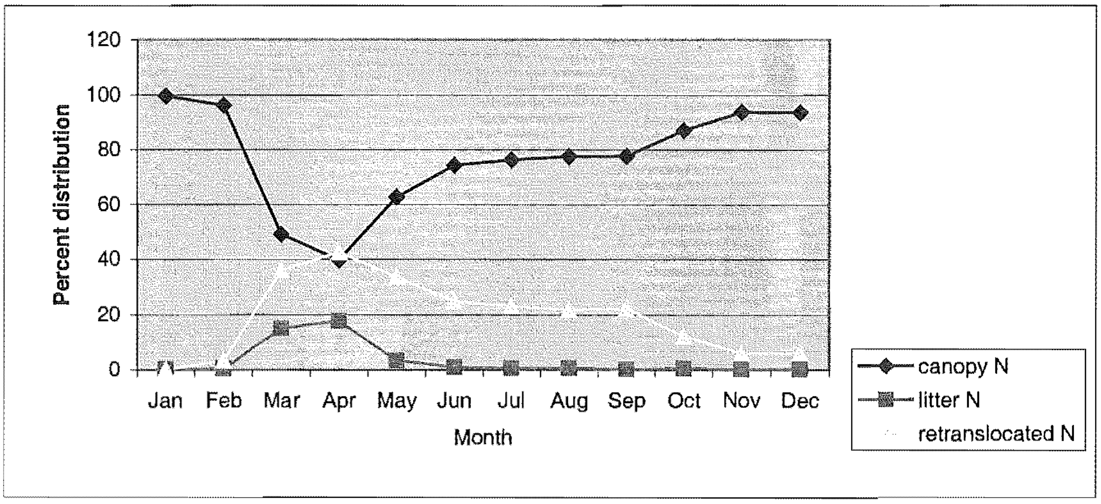

Figure 2.3: Monthly nitrogen mobility in sal foliage
(Based on data from Pokhriyal, 1988)

Besides nutrient cycling, litter contributes as a facilitator, too. Ground litter may support the defence mechanisms of trees, mainly protecting living leaves against herbivores (Feeny, 1970). Persistent leaf litter reduces the growth of grasses or other ground flora (which may be considered as weeds) and may maintain the influence of the tree canopy upon the ground flora; the trees may eventually be benefited. In particular, trees may benefit where the production of persistent litter reduces the growth of grasses (Sydes and Grime, 1981). Reduction of grass increased the annual growth of wood length of tree (*Fagus*, *Fraxinus* and *Quercus* species) by an average of 51% (ibid).

Lopping increases above-ground litter, and lopping disturbances can have significant impacts in changing the timing of litter inputs and eventually affecting the cycling rate of nutrients and carbon within ecosystems (Vogt *et al.*, 1996). Ultimately lopping may modify ecosystem nutrient storage and conservation mechanisms. Woody debris, which may be added from lopping, has substantial influence upon nutrient cycling and the activity of decomposers (Zimmerman *et al.*, 1995), and this may affect productivity in forest ecosystems. The nutrients mineralised from the decomposing litter added by lopping may not contribute to tree growth during the first year following lopping (Vogt *et al.*, 1996). However, an effect of added litter depends upon the components of litter; leaves, because of their fast decay rates, may contribute to the ecosystem relatively earlier than branches.

Litter effects on regeneraiton and seedling survival have been studied for different forest environments (Grubb, 1977; Bazzaz and Pickett, 1980; Sydes and Grime, 1981a; Sydes and Grime, 1981b; Augspurger, 1983; Augspurger, 1984; Augspurger and Kelly, 1984; Fowler, 1988; Facelli and Pickett, 1991; Molofsky and Augspurger, 1992). Litter can alter the microenvironment by decreasing light intensity, water evaporation and soil thermal amplitudes, and these factors play a significant role in regeneration in a forest stand. Seedling emergence may be delayed or aborted by litter presence, mainly by preventing contact between the root and mineral soil and impeding shoot emergence (Sydes and Grime, 1981b). Litter, owing to its low water retention capacity, appeared to strongly affect survival of the seedlings germinated on the litter surface, by imposing water stress conditions in the root environment (Hole, 1921). Such delays or stresses might also increase the risk of seedling mortality due to predation by invertebrate animals and fungal pathogens (Facelli and Pickett, 1991).

Litter increases environmental heterogeneity in a forest stand (Molofsky and Augspurger, 1992). Depending upon the species and litter thickness in a forest stand, the relevant microsite for regeneration is not large; the microsite may be no more than a few centimetres in diameter for small-seeded species (Fowler, 1988). The effect on regeneration arises more from the physical properties of the litter rather than litter quality to release phytotoxins (Sydes and Grime, 1981b). Species responses to litter vary; litter presence may promote species diversity and density of regeneration and early survival in any forest stand (Molofsky and Augspurger, 1992).

The effect of litter on regeneration and early survival could be altered by interactions with other environmental and biotic factors such as light intensity (Molofsky and Augspurger, 1992). Changes in canopy cover and litter may directly affect seed germination and initial establishment by altering micro-environmental conditions (Fowler, 1988). Litter effects on seedling density varied between lowland and lower-montane forests (Walker *et al.*, 1996).

In addition to the changes in timing of litter inputs in forest stands, lopping may influence the litter effects on regeneration by changing litter thickness and light intensity. Uneven distribution of the constituents of the lopped product (added litter) may further diversify the microsites (due to differential thickness and quality of litter), and changes may occur by removing litter from the forests (with greater exposure, the activities of decomposers may change). Leaf litter may be an important factor in forest management while considering regeneration for diverse species and their densities (Molofsky and Augspurger, 1992), varying with species and forest types.

Litter in sal forest relates to natural and anthropogenic factors, such as fire and grazing, which have been associated with sal forest management. Fire and grazing have long been considered the main factors affecting (beneficially or injuriously) sal stand development (see Figure 2.2) depending upon the forest type and local situation (Jacob, 1941; Champion and Osmaston, 1962; Maithani *et al.*, 1986; Troup, 1986; Maithani *et al.*, 1989; Lehmkuhl, 1994). Lopping for fodder and the collection of ground litter have been recorded in sal forests close to settlements (Dinerstein, 1979; Agrawal *et al.*, 1986; Prasad and Pandey, 1987a; Chopra and Chatterjee, 1990; Pandey and Yadama, 1990; Mukhopadhyay, 1991; Upadhyay, 1992; Saxena *et al.*, 1993; Sundriyal *et al.*, 1994; Bahuguna and Hilaluddin, 1995; Bhat and Rawat, 1995; Nepal and Weber, 1995; Banerjee and Mishra, 1996; Rao and Singh, 1996; Melkania and Ramnarayan, 1998), and these actions are affecting the regeneration and establishment of sal forests. Recently, sal seed collection has been an economical activity, creating large-scale employment opportunities around sal forests (Tewari, 1995; Dwivedi, 1997), and eventually affecting the regeneration and growth of sal forests.

Fire was once considered the only weapon available to foresters for controlling weeds (Champion and Osmaston, 1962). Controlled burning was prescribed to eliminate the injurious effect of dead leaves. Burning of leaf litter just before seeding was used to ensure good regeneration (Troup, 1986). Fire was extensively and intentionally used to promote regeneration and maintain the sal forest as the climax type in wet sal forest regions in India (Jacob, 1941).

Fire did not change the tree layer parameters (species composition and density) but changed the shrub structure (Rodgers *et al.*, 1986). Ground vegetation, including regenerating trees, was modified, and some species disappeared while new ones appeared (Raynor, 1940; Jacob, 1941; Nair, 1945; Maithani *et al.*, 1986; Rodgers *et al.*, 1986). In all these instances, fire increased herbs and shrubs, and importantly, the palatable plants were increased. Fire further increased the grazing attraction by reducing height of many palatable shrubs (Maithani *et al.*, 1986; Rodgers *et al.*, 1986). Availability of palatable shrubs increased the grazing intensity and negatively affected sal regeneration. Eventually, fire and wildlife grazing controlled successional pathways (Lehmkuhl, 1994). Older trees were resistant to fire, but the wounds from fire in sal trees between 15 and 35 years resulted in infection and the trees became prone to heart rot due to fungi (Bakshi, 1957).

Grazing was considered effective to check the growth of *Imperata cylindrica* efficiently to secure the establishment of sal seedlings (Rowntree, 1940; Sarkar, 1941; Rowntree, 1942). Sal being a good fodder (Rathore *et al.*, 1991), heavy grazing converted sal forests into patches dominated by grasses such as *Eulaliopsis binata, Arundinella setosa, Phragmites karka, Heteropogon contortus, Desmostachya bipinnata* and *Cenchrus ciliaris* (Dinerstein, 1979; Dakwale and Lall, 1981; Gupta *et al.*, 1996b). Grazing reduced the litter content in soil (255-385g m^{-2} to 56-104g m^{-2}) and the sapling density (260-340 m^{-2} to 20-240 m^{-2}) in sal forest (Pandey, 1994). Ill effects of grazing caused soil exhaustion preventing regeneration in sal forests (Lehmkuhl, 1994; Gupta *et al.*, 1996b).

Stainton (1972) observed stunted pole-like sal trees in open forest area close to densely populated areas in many midland valleys of Nepal, where forests were under heavy pressure of repeated lopping and intense grazing. A phytosociological study (Kumar *et al.*, 1994) of two sites (protected "core part of tiger reserve" and disturbed "buffer zone of tiger reserve") in peninsular sal forest in India showed 20 and 21 tree species in protected and disturbed sites, respectively. The study indicated changes in population structure due to disturbances, as seen in the main six tree species as trees, saplings and seedlings (Table 2.6). Although regeneration density was higher at the disturbed site, tree and sapling densities were higher at the protected site by 63% and 78%, respectively. Moreover, the disturbed site was devoid of sal saplings, indicating either direct use of these by local people or indirect effects of their activities e.g., grazing, fire or litter-collection. This may have led to the situation as reported by Stainton (1972).

Table 2.6: Densities of trees (ha^{-1}) and saplings (ha^{-1}), and seedlings ($10\ m^{-2}$)
(From Kumar *et al.*, 1994)

Species	Protected site			Disturbed site		
	Tree	Sapling	Seedling	Tree	Sapling	Seedling
Shorea robusta	183	250	14	183	0	29
Terminalia tomentosa	167	0	8	92	0	0
Bauhinia veriegata	75	260	4	33	188	1
Aegle marmelos	33	63	5	75	250	11
Diospyros melanoxylon	208	438	5	67	67	4
Emblica officinalis	117	0	1	33	63	1

Ground litter was considered for a long time to pose a mechanical problem in sal forest reproduction and accordingly, removal of dead leaves, by burning or otherwise, was strictly recommended for regeneration establishment (Champion and Osmaston, 1962; Troup, 1986). Only recently, studies (Maithani *et al.*, 1989; Schmidt *et al.*, 1993; Melkania and Ramnarayan, 1998) reported that the removal of dead leaves from sal forests drained the nutrients and reduced the fertility. Moreover, leaf litter increased uptake of all major nutrients (N, P, K, Ca and Mg) in sal forests (Pakrashi, 1991; Prasad *et al.*, 1991).

Thus, the responses to lopping and litter-removal, their impacts and compensatory behaviour, vary with species, age, site, stocking and the species composition of the forest. An understanding of specific ecological niches is necessary for prescribing such treatments in forest management. As the present research focused on the lopping effects on sal forest, the next section deals with the specific ecological niches of sal forests - types, successional stages, phenology, stand development process, and growth patterns.

2.4 Sal forest ecology and productivity

2.4.1 Successional stages of sal forests

Sal forest's present status is due to the actions and interactions of environmental and biotic factors, and is explained in terms of plant succession theories (Champion and Osmaston, 1962; Troup, 1986). The developmental process involves progression and retrogression (Figure 2.2). Grazing and fire are prevalent in sal forests, and the extent of their presence affects the successional pathways into progression and retrogression (Lehmkuhl, 1994).

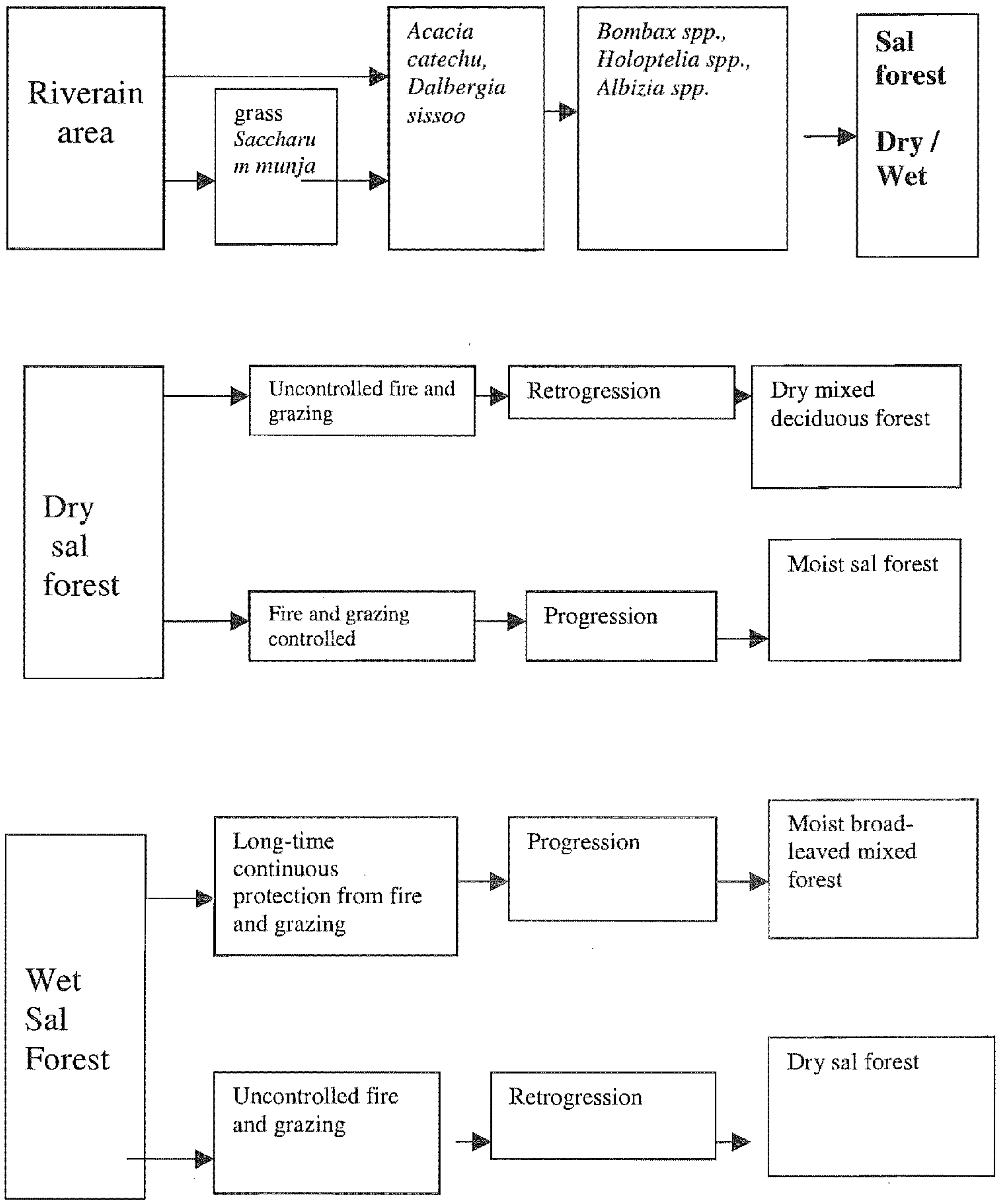

Figure 2.2: Successional phases of sal forest
(Based on Jacob, 1941; Champion and Osmaston, 1962; Troup, 1986; Maithani *et al.*, 1989)

2.4.2 Stand structure

Sal is gregarious and dominant in its stand (Champion and Osmaston, 1962; Troup, 1986). It is considered to be deciduous as it changes leaves every year, and evergreen as the tree is hardly leafless. A sal tree was recorded with 45 m height, 25 m clear bole, and a girth of eight metres in Nepal (Troup, 1986). Sal forest's top canopy reaches a height of 30-35 m and trees have a girth of four metres in favourable localities, and the forest consists of many other layers of trees and shrubs. Stainton (1972) recorded species in various strata of Bhabar/Tarai and hill sal forest (Table 2.7), and Rana *et al.* (1988) noted species in two types (by age) of sal forests (Table 2.8). The other species reveal the various types of sal forests, i.e., dry, moist or wet, and are found in varying densities depending upon the edaphic and biotic conditions, and constitute a stratified height structure.

Table 2.7: Species in different strata
(from Stainton, 1972)

Canopy	Bhabar/Tarai	Hill
Top	*Shorea robusta, Terminalia tomentosa, T. belerica, T. chebula, Adina cardifolia, Anogeissus latifolia, Lannea grandis, Scleichera trijuga, Syzygium cumini*	*S. robusta, Lagerstroemia parviflora, Anogeissus latifolia, Adina cardifolia, Semicarpus anacardium, Bauhinia variegata, Dillenia pentagyna, Buchnania latifolia*
Lower	*Mallotus philippinensis, Semecarpus anacardium, Dillenia pentagyna, Kydia calycina, Apotosa dioca, Casearia tomentosa, Buchnania latifolia*	*Nyctanthes arbortristis, Kydia calycina, Leucomeris spectabilis, Glochidion velutinum, Symplocos racemosa*
Shrub	*Ardisia humilis, Zizyphus rugosa, Clausena spp., Barleria cristata*	*Hamiltonia suaveolens, Phoenix humilis, Indigofera pulchella, Flemingia strobiliferra*
Lianas	*Spatholobus roxburghii, Bauhinia vahlii*	*Spatholobus roxburghii, Bauhinia vahlii*

Table 2.8: Species in different strata in two sal forests

Layer	Spp in old-growth forest	Spp in seedling coppice forest
Tree	*S. robusta, Mallotus philippinensis, Cassia fistula, Lagerstroemia parviflora, Litsea polyantha*	*S. robusta, Mallotus philippinensis, Lagerstroemia parviflora, Litsea polyantha, Ehertia laevis, Syzygium cumini, Pterocarpus marsipium, Bauhinia variegata*
Shrub	*Murraya paniculata, Clerodendron infortunatum, Colebrookia oppositifolia, Flemengia semialata, Justicea pubigera.*	*Murraya paniculata, Clerodendron infortunatum, Colebrookia oppositifolia, Flemengia semialata, Justicea pubigera.*

2.4.3 Phenology

Depending upon edaphic factors and microclimate, a sal forest's phenology ranges from deciduous to evergreen and extends from tropical to sub-tropical. Leaf fall usually starts in late winter (February) and is completed by the end of April (Misra, 1969). As the sal forest consists of many other species in different layers, the phenology of the sal stand interacts with the phenology of these species (Table 2.9). Maximum leaf fall is from mid-February to mid-May (Pokhriyal *et al.*, 1987; Singh *et al.*, 1993a). Sal trees produce seeds every year; a good seed year is normally every third year. Seed production in sal varies (500 kg ha^{-1} during early 1980s) from year to year and from tree to tree (Tewari, 1995). Seeding is normally from mid-May to mid-June.

Table 2.9: Deciduous or evergreen habits
(Based on Krishnaswamy, 1954; Krishnaswamy and Mathauda, 1954)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Butea monosperma	--- ***	--- ***	--- +++ ***	--- +++ *** 000	+++ 000							
Cedrela toona	---	---	+++	+++ *** 000	*** 000	000					---	---
Mangifera indica	---	--- ***	--- ***	-- +++ ***	+++	+++ 000	+++ 000	000				
Shorea robusta			--- ***	--- +++ ***	--- +++ *** 000	+++ 000	+++					
Syzyzium cumini		---	--- +++ ***	+++ ***	+++ *** 000	000	000					
Terminalia tomentosa		---	---	---		+++	+++	+++				

--- leaf fall; +++ new leaf; *** flowering; 000 fruiting

2.4.4 Stand development

Stand development depends on the nature and extent of interactions among individuals, and so competitive processes are reflected in any forest stand development. Competition results from the processes of resource allocation among individuals and species (Perry, 1985). The process can be modified depending upon the objectives of management, but the objectives may not be always achievable. The processes are highly influenced by the given environmental-social-economic setting, so it necessitates the understanding of all stages of development, i.e., from regeneration to maturity. Sal stand development is best explained from the perspective of sal trees, as it is a dominant and purposively managed species. Development of other species largely depends upon the status of sal trees.

Sal forest regenerates from seed origin or by coppicing; sprouting from root suckers is also very common. Trees of both coppice and seed origin produce fertile seed, and there is no difference in the vigour of the seedlings from coppice or seed origin (Troup, 1986). Although Yadav *et al.* (1986) noted the middle girth class (81-90 cm girth at breast height) as the best size for good quality seed, the size of the tree has no apparent effect on the viability of the seed (Troup, 1986). The seed loses its viability within a week, and so if the monsoon, which usually starts in late June, is delayed, the seed may fail to germinate.

Sal seeds have wings, and are dispersed by wind about 100 m from the mother tree (Jackson, 1994). The germination rate is very high (over 90%) in sal, provided the seed gets rain within a week. A large number of seeds germinate annually. Sal tends to regenerate as a mass of seedlings where conditions (light, soil, moisture with good drainage) are favourable, and forms more-or-less even-aged crops, which are relatively pure, or it forms the bulk of the stock in mixed stands (Troup, 1986). Depending upon environmental factors, sal encroaches into miscellaneous forests, or sal is ousted by other species (Figure 2.2).

Germination and survival of sal was much better in full overhead light with little side-shade than in the shade, and in particular root development in the open was much better than under shade (Troup, 1986). Root lengths were 35.8 and 53.1 cm in two plots in the open, as against 11.9 and 18.5 cm in two plots in the shade. Vigorous growth of seedlings could be obtained by the complete removal of the overhead canopy (Troup, 1986).

Sal has a remarkable character of perennating, such as ability to coppice, and the seedling sends out young shoots after having been cut back. This process repeats year after year, and allows the cut-over sal forest to regenerate. Protection against grazing of degraded (or cleared for agriculture) land that was previously sal forest will result in numerous young sal shoots of uniform height, arising from roots that have survived in the ground (Jackson, 1994).

Sal regeneration can be established in most of its range provided that fire and grazing are not excessive. However, regeneration has been a serious problem in sal forest management in some parts of India, and efforts initiated since the beginning of this century have not been yet successful. Hole (1921) commenced a series of experiments in 1909 in this regard and concluded that two main factors - soil water content and aeration of soil - were responsible for the failure of regeneration establishment.

Soil water content is related to drought/precipitation and soil type, whereas bad soil aeration is caused by heavy rainfall, the presence of organic matter such as dead sal leaves, and heavy grazing (Troup, 1986). The injurious actions of leaf litter were correlated with an accumulation of carbon dioxide in the soil solution and a low oxygen content, and also the presence of toxic substances produced mainly by decomposition of organic matter (Troup, 1986). However, such actions and substances are injurious only under conditions of bad aeration coupled with high water content (ibid.). Sharma *et al.* (1985) suggested that poor or deficient soil aeration during monsoons (due to high magnesium), soil stress coupled with hardness during dry periods, and unfavourable topographic location seem to be responsible edaphic factors in sal regeneration failure. Nevertheless, the information on the edaphic factors in relation to sal regeneration establishment is still scanty (Tewari, 1995).

Troup (1986) explored the mechanical effects of litter on establishment and found that seedlings germinated on a layer of dead leaves under shade developed satisfactorily above ground during the first rains. In such instances, the taproots, instead of descending into the mineral soil, spread laterally between the layers of wet leaves deriving sustenance from the moist earthy matter there, and sending out long fine lateral rootlets. All these seedlings died off when the leaf layer dried after the end of the rainy season. Such effects are reported for other tropical species, too (Molofsky and Augspurger, 1992). On the other hand, seedlings germinated on bare ground adjacent to the plots, both under shade and in the open, produced long taproots and achieved a firm hold in the mineral soil.

Qureshi *et al.* (1968) studied the effect of weeding and soil cultivation under three light regimes (open, partial-shade and sal-plantation) on the growth and establishment of sal seedlings, and found weeding and cultivation beneficial only in the open and in partial shade. Lack of light was apparently responsible for poor growth and survival in both treated and untreated areas under plantation. Khan *et al.* (1986) found higher survival and better growth of seedlings in the forest periphery than under dense canopy, signifying the role of light in forest regeneration and early growth. Light is thus very important in the development of sal stands. Light plays mainly two roles, increasing photosynthesis and ground temperature, which accelerates litter decomposition.

Growth of sal is relatively faster in the early stages; growth of 14-year-old sal forest is given in Table 2.10. Rana *et al.* (1988) reported on the net biomass production for sal old-growth forests and sal seedling-coppice forests (Table 2.11). Carbon fixation in these forests was found to be 9.3 (for old-growth) and 10.1 (for new-growth) t ha^{-1} year^{-1}, indicating greater carbon accumulation efficiency in young forest than in old forest (Rana *et al.*, 1989).

Table 2.10: Growth of 14-year-old sal forest
(From Jackson, 1994)

Species	Stem ha^{-1}	Mean height m	Mean dbh cm	Volume over bark m^3 ha^{-1}	MAI over bark (0-14 years) m^3 ha^{-1}
Sal	928	8.5	9.1	28.8	2.06
Other species	711	8.8	9.1	21.3	1.52
Total	1639	8.6	9.1	50.1	3.58

Table 2.11: Total net biomass production in sal forest
(Based on Rana *et al.*, 1988)
(t ha^{-1} $year^{-1}$)

Layer	Sal old-growth forest		Sal seedling-coppice forest	
Tree layer	15.3		18.5	
S.robusta		12.8		15.4
M.philippinensis		0.7		1.4
Other species		1.8		1.7
Shrub layer	1.2		1.1	
Herb layer	2.1		1.3	
Vegetation total	18.6		20.9	

Data on the productivity of different woodlands in terms of volume of marketable stems are abundant but relatively scarce with regard to the weights of bole, branch, leaf and root material. With an increase in age, the standing biomass increased in sal plantations (Singh and Ramakrishnan, 1981) and natural stands (Misra *et al.*, 1967), and non-photosynthetic / photosynthetic ratio increased (Table 2.12). The non-green to green ratios indicate three major shifts (1.94-5.43 for ages nine to thirteen years; 10.96-12.62 for ages 15 to 19; and 40-41 for ages 30 to 50 years), and clearly shows that dry matter accumulation is greatest between 30-50 years of age (Misra, 1969). However, increment varies with site class, and a yield table for two site qualities is presented in Table 2.13.

Table 2.12: Proportion of green and non-green biomass in different stands of sal
(From Misra *et al.*, 1967; Singh and Ramakrishnan, 1981)

Biomass in t ha^{-1} except for ages 18, 30 and 50 years (shaded columns), where it is kg $tree^{-1}$

	Age in years								
	9	11	13	15	17	18	19	30	50
Non-green	1.20	6.88	19.82	28.41	37.72	122.10	54.53	228.40	566.80
Green	0.62	2.85	3.65	2.57	2.99	10.90	4.35	5.70	13.70
Ratio	1.94	2.41	5.43	10.96	12.62	11.20	12.54	40.00	41.00

Table 2.13: Growth of sal from Indian yield table
(From Jackson, 1994)

Age	Quality I			Quality II		
	Height (m)	Dbh (cm)	MAI $M^3ha^{-1}\ yr^{-1}$	Height (m)	Dbh (cm)	MAI $M^3ha^{-1}\ yr^{-1}$
10	-	8.1	2.8	-	4.6	0.1
20	14.9	14.2	4.5	7.0	7.4	0.8
50	25.9	29.2	8.6	11.3	17.7	1.9
100	36.9	48.3	11.2	17.7	29.5	3.1
120	39.6	54.9	11.0	18.3	33.3	2.9

Boles, branches and roots respectively constituted 60%, 24.9% and 14.7% of total non-photosynthetic biomass (233.4 t ha^{-1}) in a forest dominated (70% of total density and basal area, 95% of non-photosynthetic biomass) by *Shorea robusta, Anogeissus latifolia, Buchnania lanzon* and *Terminalia tomentosa* (Bandhu, 1970). The weights of all tree components increased with increasing tree diameter, and of the total dry weight of the trees, bole accounted for most of the weight in all tree categories (60, 61 and 66 % in suppressed, average and dominant trees, respectively) in sal forest (Kaul *et al.*, 1979). In another study, Singh and Ramakrishnan (1981) partitioned the biomass of sal trees of different aged stands into bole, branch and leaf (Figure 2.4). Bole biomasses were 53, 58, 79, 83, 88 and 88% of the total biomass at the ages of 9, 11, 13, 15, 17, and 19 years, respectively. Bole biomass and diameter at breast height are along the same trend, and they cross at the age of ca 14 years interchanging slopes.

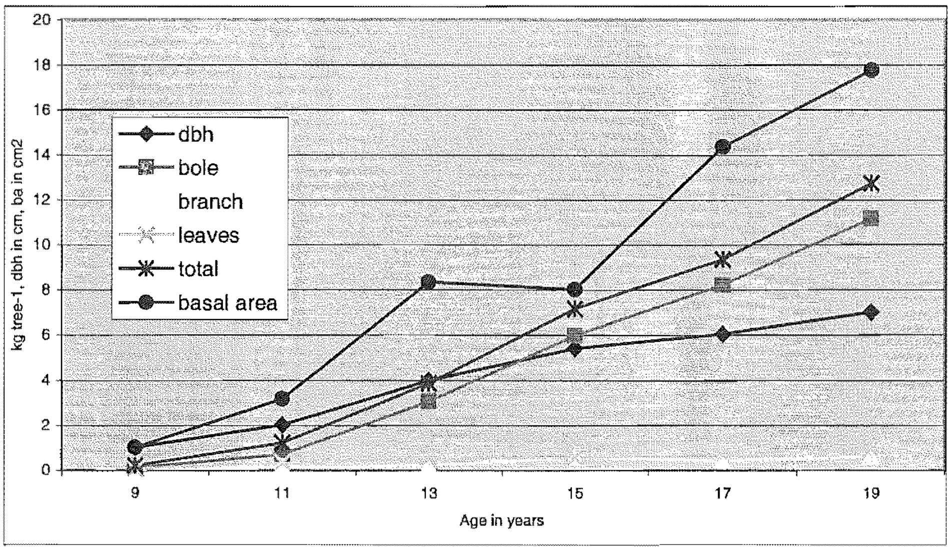

Figure 2.4: Partitioning biomass and dbh/ basal area curves

Of the total above-ground biomass of the tree layers in sal forest, 77% and 70% were found in the bole in old-growth and seedling-coppice forests, respectively (Rana *et al.*, 1988). [Singh and Chaturvedi (1983) and Singh *et al.* (1993b) found a linear relationship between circumference at breast height and current or mean annual net productivity for the young natural sal forest. Although correlation between girth and height product and biomass were also significant, girth at breast height is used more frequently in establishing the allometric relationship with biomass for sal (Singh *et al.*, 1993b).

Rana *et al.* (1988) found significant allometric relationships between biomass of the tree components (bole, branch, twig, foliage) and circumference at breast height. Similarly, positive correlation coefficients were recorded between height, girth at breast height and wood biomass and were highly significant (Suri and Dalal, 1963; Suri, 1968; Gangopadhyay *et al.*, 1990). Rao and Chaturvedi (1971) found a linear relationship between the oven-dry foliage weight and diameter at breast height for sal.

Raman (1976) studied the productivity of sal plantations ranging from 8 to 26 years old, and noted the same trend between basal area and net primary productivity (based on annual litter fall and current annual increment in tree biomass). The study showed 14.62 t $ha^{-1}year^{-1}$ (corresponding to basal area of 29 m^2 ha^{-1}), as the highest productivity indices attained at the age of 18 year (but dry matter accumulation based on non-green/green ratio was reported greatest between 30-50 years of ages, see Table 2.12). Sharma *et al.* (1989) used the increment in stem timber volume as a productivity index for sal forest mixed with *Mallotus philippinensis*. As the above-reviewed studies indicate, the parameters such as diameter at breast height, basal area and stem volume are good indictors of net productivity in sal forests.

Based on the above-reviewed literature, fire and grazing are the main factors associated with successional phases of sal forests (see Figure 2.2). Sal forests located close to settlements are affected by intense lopping, litter removal and grazing. Lopping, litter removal, grazing and fire are interrelated and depend upon the quantity and quality of available fodder and litter in the forest. Local people need to extract fodder and litter from sal forests without adversely affecting forest growth and regeneration. This thesis focuses on studying the effects of fodder and litter removal on growth and regeneration in sal forests, which have been rarely studied.

2.5 Hypotheses for experiment

On the basis of sections 2.3 and 2.4 above, the aims of the experiment described here were:

i) to test the hypothesis that a single removal of green branches up to 80% of tree height would have no impact on growth (diameter, height, basal area and volume) of lopped compared to unlopped trees;

ii) to test the hypothesis that lopping changes understory species composition;

iii) to test whether removal of ground litter changes the growth of trees;

iv) to test that removal of ground litter changes understory species composition; and

v) to test whether lopping and litter-removal effects interact in stem growth and regeneration.

2.6 Methodological perspectives

The research focuses on investigating ways of meeting people's need by understanding ecological processes. Methodological perspectives are drawn from two aspects - experiments and ethnoscience. Experimental studies were conducted in two forest stands, and ethnoscience perspective was used in learning the indigenous knowledge systems from users of the same forests. Following a brief description of these perspectives, detailed methodology is given in the next chapter.

2.6.1 Experimental perspective

Forests were inventoried for baseline information on species composition, diameter and height classes and general condition. The inventories helped in selecting areas for experimental plots. Community forests typically have a differential use intensity from the edge to the interior. For forest inventory, transects were established within the forest perpendicular to the edge. Considering the time available for research, immediate effects such as changes in diameter-at-breast-height, basal area, tree height, volume at tree and stand levels, and regeneration were considered appropriate parameters for assessing treatment effects, and hypotheses were tested accordingly.

During stand development, early-emerged dominant trees are most likely to survive and dominate as the stand matures (Sutton, 1973; Osawa, 1992; Nilsson and Albrektson, 1994; Ward and Stephens, 1994). Average tree diameter and height for any stand correlate with the stand density, whereas diameter and height of dominant trees vary less with stand density (Menguzzato and Tabacchi, 1995). Biologically, dominant trees respond quickly to any addition of limiting resources with enhanced growth (Dhote, 1997). Thus, the growth patterns of dominant trees may reveal productivity of any forest stand more closely than that of average trees. Growth (diameter, height, basal area) of dominant trees is considered the most relevant statistic to assess the growth of even-aged forest stands (Meng and Seymour, 1992; Morris and Parker, 1992; Cobb *et al.*, 1993; Pettersson, 1993; Dhote, 1997).

The plots were comprised of mixtures of trees (species, age and stocking). Selecting a fixed number of trees per plot was thought to be an appropriate measure for comparing mean tree diameter and height increments (Husch *et al.*, 1982; Philip, 1994). Selection of dominant trees depends on the planned stand density i.e. 1000 or 2000 trees ha^{-1}. In the present research, the largest 10 and tallest 10 trees were selected per plot for additionally comparing treatment effects on mean tree diameter and height increments.

2.6.2 Ethnoscience perspective

Ethnoscience is defined as "folk description" (Agar, 1986), or "a set of techniques that permits a formal understanding of indigenous knowledge systems" (Warren, 1976). Native peoples possess biological knowledge and information (Agar, 1986; Werner and Schoepfle, 1987; Rusten, 1989; Brush, 1993), and have sophisticated knowledge of their ecological circumstances (Conklin, 1957; Posey, 1985). Furthermore, to the communities who have been stewards of the ecosystems around them, the environmental knowledge embedded in folk taxonomies of plants, soils, and production zones has ecological value (Richards, 1985; Brush, 1993). Their knowledge is indispensable in technology development, but it must be seen in context (Tripp, 1993). Thus indigenous knowledge systems provide guidelines concerning potential future directions for scientific research (DeWalt, 1994). Ethnosciences have been successful in learning the indigenous knowledge system in various fields such as botany, pharmacology, anthropology, ecology, and economics (Martin, 1995).

Van-den-Berg (1984) did an ethnobotanical study from a market study. Boster (1984) conducted an ethnobotany study by asking informants to give native plant names, information about their culturally important properties and yields of economic species, and took transects of their gardens. Prance's (1984) study of the use of edible fungi by Amazonian Indians was based primarily on field visits, recording common names of the botanical species, and found women more resourceful than men. Boom (1989) followed the methods of "artifact/interview" technique, and 'inventory/interview" technique. Thaman and Devoe (1994) conducted an ethnobotanical study with a questionnaire, key informants and group discussion, and compared these to a botanical survey.

Balee and Gely's (1989) method consisted of an extensive plant collection from different vegetation zones, and identified locally recognized vegetation zones. They inquired into the utility of these resources in the local language, and observed resource use. In a similar study, Anderson and Posey (1989) explained their method as the collection of cultural data on the use and management of the vegetation, and conducted a botanical inventory and elicited data on plant use and management. Abbiw (1990) recorded the uses (both past and present) of plants through interview and oral history.

Ethnoecology may be defined as indigenous perceptions of "natural" divisions in the biological world and plant-animal-human relationships within each division (Posey *et al.*, 1984). Researchers often begin to understand ethnoecology by describing the different ecological zones recognized and transformed by local people (Martin, 1995). Ethnoecology is confined to the study of knowledge deemed important to the interaction of a population and its environment (Bellon, 1991). Main aspects include the soil, vegetation, animals, climate, land use, and their interactions. Some individuals may possess more biological knowledge than others, and many of them have a keen awareness of the interconnectedness of plants, animals and soils - their interrelationships and ecology (DeWalt, 1994). Most of the qualitative data on ethnoecology are being obtained through field visits with knowledgeable informants, and discussions. Martin (1995) has presented a summary of various domains of folk ecological knowledge and some of the principal dimensions on which they are classified.

Ethnobotanical and ethnoecological theories have enabled study of the status of botanical and ecological knowledge among indigenous people and groups. Such studies are still confined to presenting native understanding of botany and ecology. Efforts to explore indigenous knowledge of the management of forest resources are rare (Gomez-Pompa and Kaus, 1990). Ethnosilvicultural issues have been of minor concern in ethnobotanical and ethnoecological studies. Ethnosilvicultural study consists of efforts to present indigenous knowledge of the silvicultural aspect of forest management, and includes qualitative and quantitative aspects of growing forests to meet human needs. Methods for understanding ethnosilviculture consist of interview, observation, discussion with the forest users to ascertain their understanding of silviculture in general, and interactions and mutualism in particular.

Ethnosilvicultural study was done in emic (Pike, 1967) or cognivist perspective, in which silvicultural phenomena were examined from the native viewpoint. As there were native ways of classification of fodder trees (Rusten, 1989; Rusten and Gold, 1991; Thapa, 1994), and soil

(Chadwick and Seely, 1996), there were also indigenous way of understanding silvics of forest species. For example, local people living near research sites classified trees as *sepilo* (shade-forming), *rukho* (making area unproductive), *malilo* (making productive land), *osili* (moist), etc. However, an etic (Pike, 1967) or materialist perspective was also useful while making observations on the use of NTFPs. Sometimes there were differences between what people did and what they said they did (Harris, 1974), so a mix of emic and etic approaches was necessary to understand indigenous silvicultural knowledge. Mixture of all these techniques and methods were followed to explore the indigenous knowledge of plant products and ethnosilviculture in the present research.

CHAPTER III. RESEARCH SITE SELECTION AND METHODOLOGY

3.1 Selection of study site

Preliminary contacts were made with the senior forestry officials in the Ministry of Forest and Soil Conservation, and Department of Forests Nepal in Kathmandu, and they were briefed about the research proposal. Professionals involved in the management of forest in general, and community forestry in particular, were consulted for their comments and suggestions on the research.

My continued involvement of nearly two decades in the development of community forestry in Nepal facilitated identification of potential areas for conducting the proposed research. The proposal was floated to a few organisations engaged in community forestry development, seeking their interest and collaboration in conducting research in their respective project/programme areas.

CARE-Nepal's Forestry Partnership Project (FPP) found the objectives of the proposed research supportive of and complementary to the overall goal of their activities in project districts located in the mid-western region of Nepal, and expressed their interest in participating in the research. General assessment of the status of community forestry programmes in the project area was then necessary, as the research was to be conducted in forests managed by local forest users groups in order to yield practical results.

Realizing the high potential for the development of degraded forest resources, His Majesty's Government (HMG) with support from USAID, has been developing forestry in the district as part of the Rapti Integrated Rural Development Project since the early eighties, covering five districts including Dang (Amatya, 1986). Currently, funding is through HMG/USAID's Environmental and Forestry Enterprises Activity (EFEA), and community forestry is the major component in the forestry development. Care-Nepal's FPP is responsible for implementing EFFA's community and private forestry programme. A substantial area of forest is managed by the forest users in these districts. Subsequently, after several meetings and discussions with officials, field research was sited in Dang District. Professionals with work experience in Dang were asked for their advice to select the forest. A preliminary list was made before departing for Dang.

3.1.1 Dang District

The Dang District, an area of 297,339 ha, lies between $27^{0}37'$ and $28^{0}29'$ N latitude and $82^{0}20'$ and $82^{0}54'$ E longitude, 400 km west of Kathmandu (Figure 3.1). The district's terrain falls in the Mahabharat (mid-hills) and Chure/Siwalik (lower hills) ranges. Twin valleys, Dang (between the Mahabharat and the Chure) and Deukhuri, (in the Chure range) are the main part of the district. Forest coverage in Mahabharat and Chure ranges are 74,279 and 117,876 ha respectively (Kandel, 1998). Elevation varies from 100 m to over 1000 m above sea level. The latest census recorded the population of Dang as 354,413 people in 56,099 households (CBS, 1998).

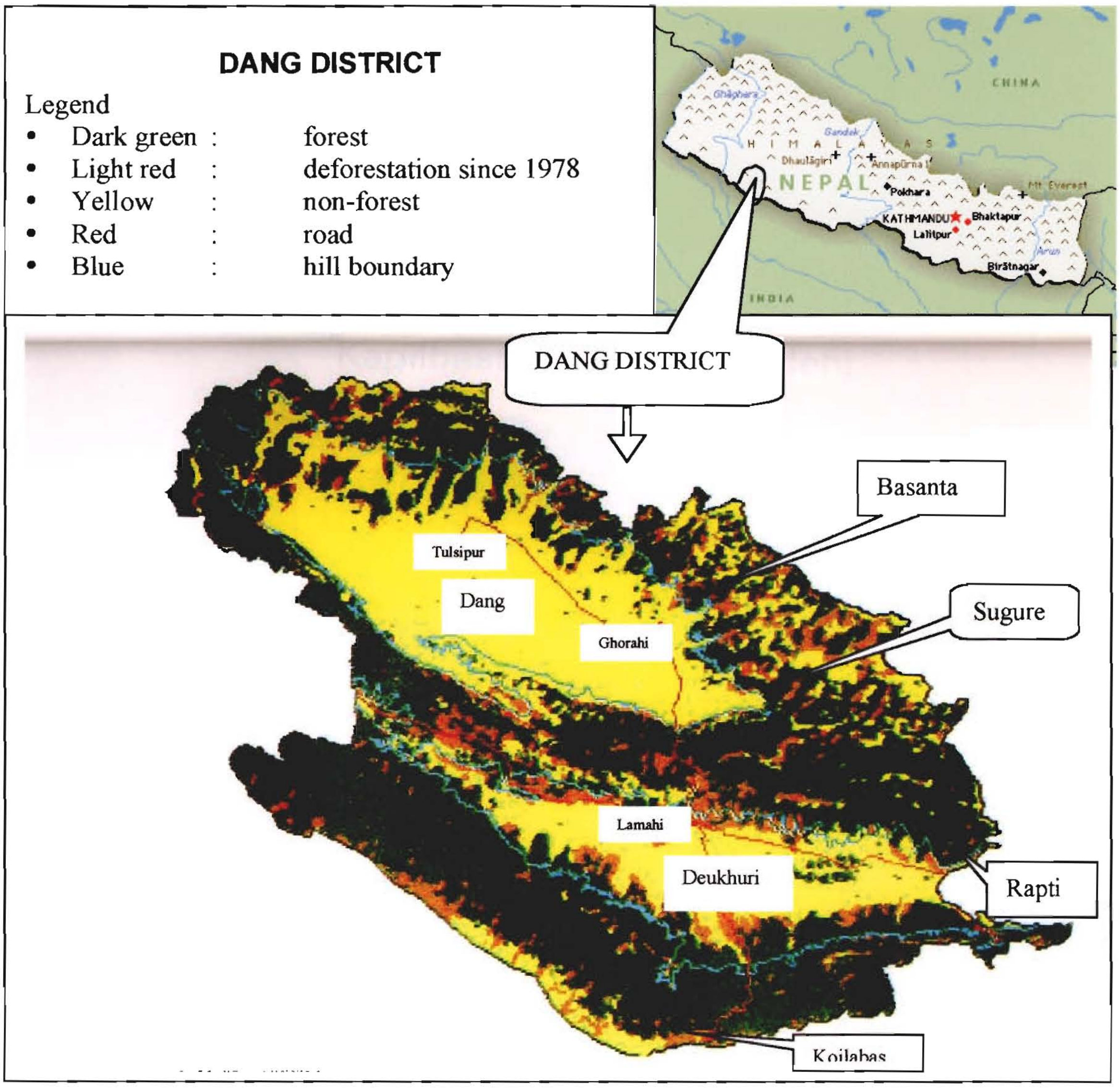

Figure 3.1: Dang district land use showing research sites
(HMG, 1993b)

The Dang and Deukhuri valleys have a warm and humid climate; climatological data for these valleys are presented in Figures 3.2 (for Basanta) and 3.3 (for Rapti).

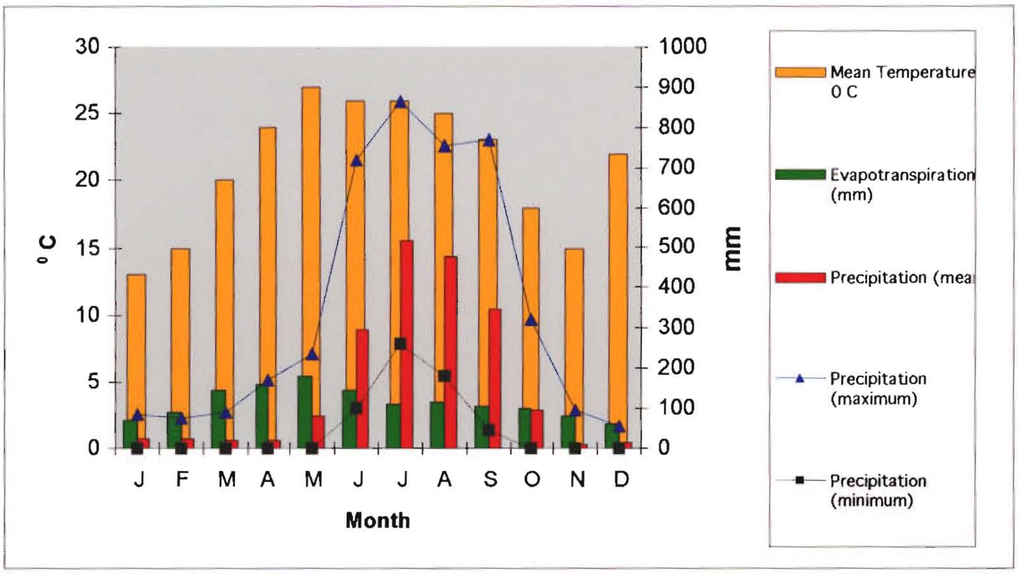

Figure 3.2: Climatological data for Ghorahi (Based on 26 years' records)
(From Nayaju, 1999)

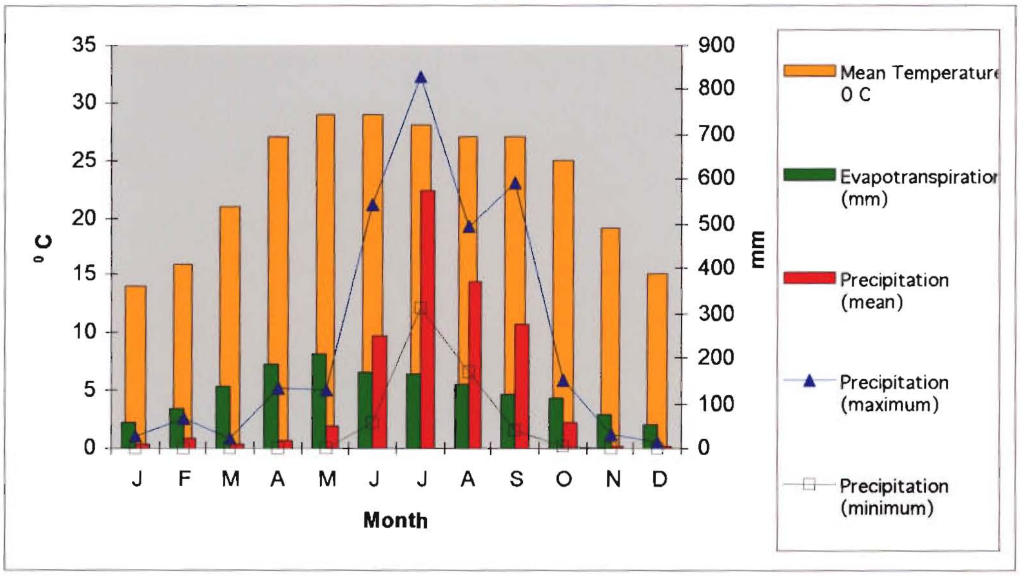

Figure 3.3: Climatological data for Koilabas (Based on 10 years' records)
(From Jackson, 1994)

Dang district was once rich in timber and non-timber forest resources, and so was well known to the central authority since the functioning of the Forest Department in the 1940s. Harvesting was the only activity carried out as management, resulting in the degradation of resources by the early 1970s. A recent landuse study (ICIMOD, 1996) recorded 180,115 ha, 17,158 ha, 8,905 ha, and 91,161 ha as forest, shrubland, grassland and agricultural land, respectively.

By the end of fiscal year 1996/97 (July 1997), 25,267 ha of forest land had been handed over to 195 forest users groups involving 32,336 households and 218,699 people (Table 3.1).

Table 3.1: Status of community forests handover in Dang
(From Kandel, 1998)

Fiscal year	**CFUG #**	**Area ha**	**Household #**	**Population**	**FUG Committee members**	
					Male	Female
1988/89	1	167	218	1369	9	2
1989/90	0	0	0	0	0	0
1990/91	5	1769	1353	9305	40	23
1991/92	17	766	1500	11484	147	29
1992/93	25	1783	3829	25415	284	31
1993/94	10	1697	2220	13430	103	14
1994/95	28	1261	4003	27716	242	65
1995/96	66	11094	12038	81608	653	161
1996/97	43	6730	7175	48372	314	239
Total	195	25267	32336	218699	1792	564

3.2 Community forest users group (CFUG) selection

Contacts were initially made with the officials of the district forest office (DFO), EFEA, and FPP in Dang District, and the status of community forestry development in the district was sketched (Table 3.1). Further discussions were held with the field forestry personnel. The preliminary list prepared in Kathmandu was also discussed. Objectives and methodologies were explained, and the requirements described below for selecting any CFUG for participation in the research were explained as broad guidelines.

Although the community forestry development programmes started in the late 1970s, the first few years of effort were invested in identifying appropriate local institutions. It was only in the late eighties that forest users groups were entrusted with forest for management (HMG, 1989). In the case of sal forests, most of the forests entrusted were degraded land, and areas with few trees left (Stainton, 1972; Jackson, 1994). Such areas responded to protection efforts with profuse natural regeneration, and they are now in need of management prescriptions. Accordingly, young sal forests were preferred for conducting the research.

Forest policy has recognised 'forest users groups' as institutions for community forest management, and such groups are of irregular shapes and sizes in forest, people or both (Gautam, 1993b). Community forests vary in area from less than a hectare to several hundred hectares. It was not possible to conduct research in small forests, as this could have resulted in abandoning uses for the research period. So one of the selection criteria was sufficient area to allow exclusive allocation of approximate 5 ha for continuing research.

A strong community institution was required to protect experimental plots, so that the research would suffer no adverse effect while treatments were implemented. An institution could be involved in the processes of decision making, implementing decisions and resolving conflicts. Finally, but importantly, the CFUG's interest in participation was the main criterion for selection. The aim was a participatory research approach, which could not be achieved through pressure or dictation from outside.

These criteria yielded a list of potential CFUGs for participation in the research, and the list was different from the list generated in Kathmandu.

The CFUGs listed as potentials were consulted, and the forests in question were then visited. Operational plans were studied to see whether or not provision for conducting research was made. Although several CFUGs were supportive and interested, their protection statuses became a limiting factor, as most of these allowed free grazing at least a few months in a year. Few CFUGs were found effectively implementing management decisions including controlling grazing. Finally the following community forests (CFs), and respective users, were selected to conduct the field research (see Figure 3.1):

- Basanta-hariyali community forest, Ghorahi (also noted as Basanta or BH)
- Rapti community forest, Bhalubang (also noted as Rapti or RP)

3.2.1 Basanta-hariyali community forest

The Basanta-hariyali community forest is located in Tribhuvan-Nagar Municipality of the Dang valley, and is 2 km north of Ghorai, the district headquarters. It occupies 141 ha of undulating plain and hillocks between the elevations of 750 m at the fringe of settlement, and 1000 m at the boundary of the national forest (Figure 3.4).

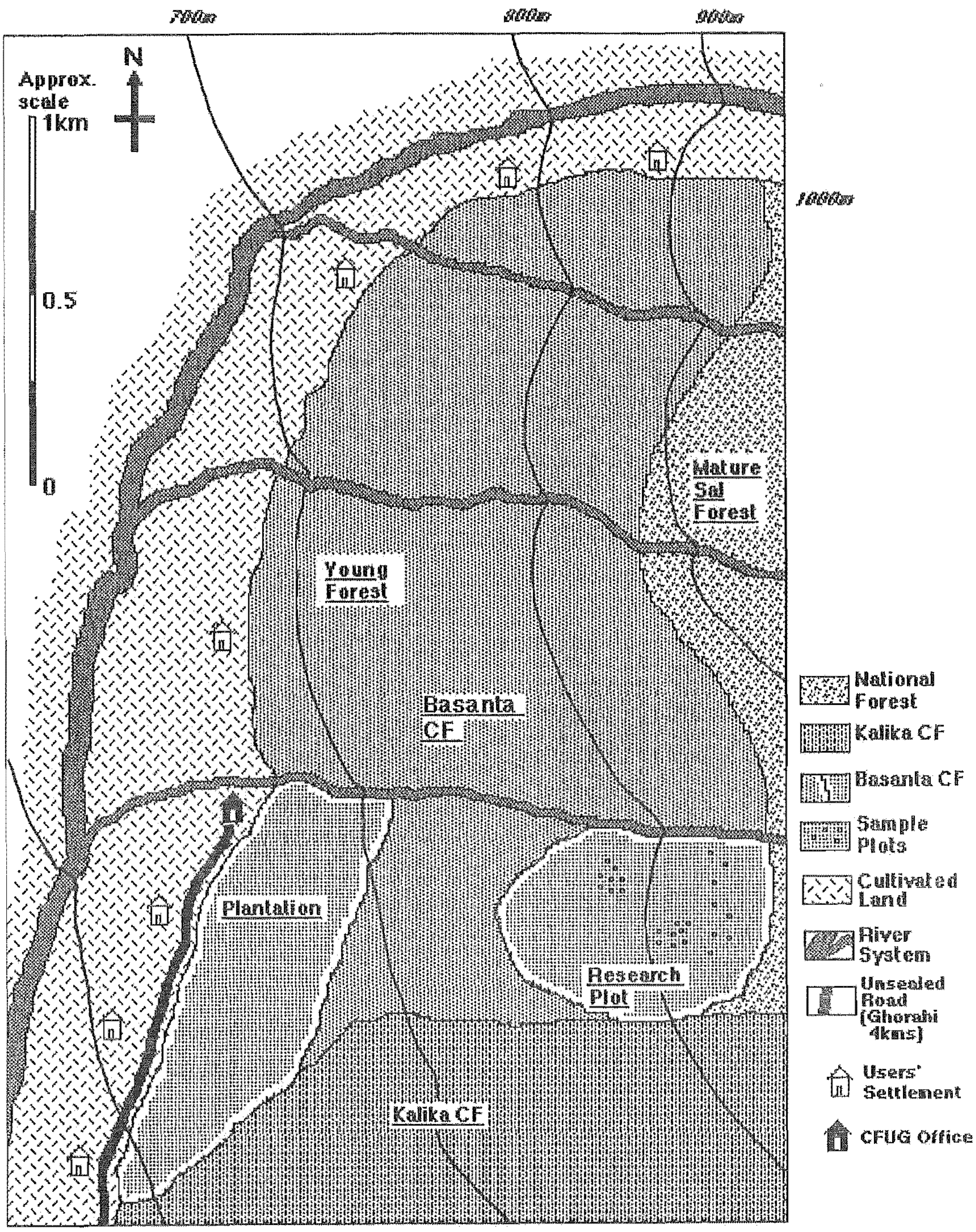

Figure 3.4: Basanta-hariyali forest

Basanta-hariyali forest is classified as dry siwalik sal type (Champion and Seth, 1968), and bhabar sal forest (Stainton, 1972). Sal is the dominant species; however, many other species are also present in lower layers. Biotic influences, mainly from ever-increasing population and urbanization, affected the forest, and as a result different categories - matured natural, regenerating young, and shrubland - are visible. Besides this, a small portion of the forest area, close to settlement, is planted with *Dalbergia sissoo* and *Leucaena leucocephala,* after the sal forest was turned into open, bare land sometime in the early 1980s.

Users of the forest are settled on its periphery. Users, who have mostly migrated from the neighbouring hills, have been settled in this area since the 1950s. However, the settlement has a longer history than this, and some of the earliest settlers remain in the users group. Figure 3.5 reflects the composition of users, of which *Chaudhary* were the earliest settlers.

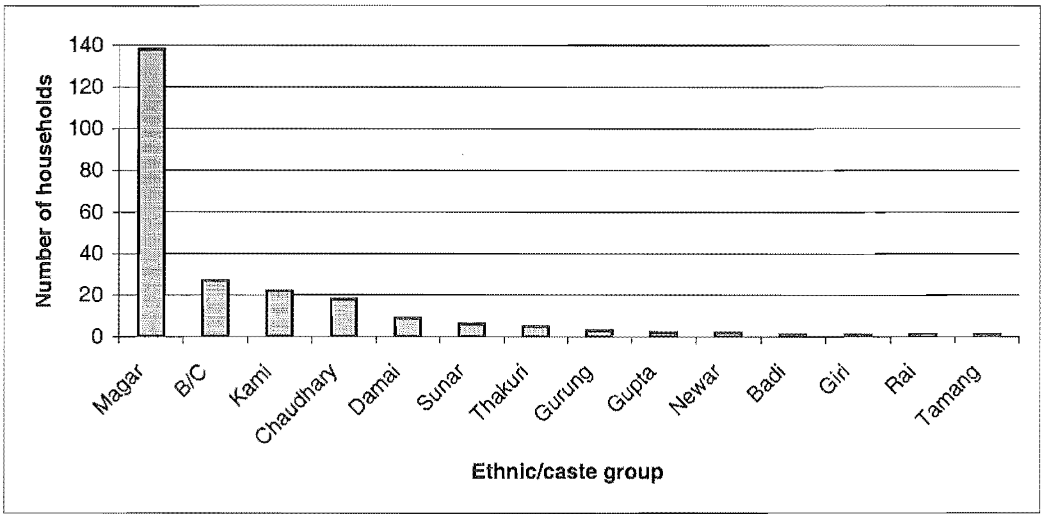

Figure 3.5: Ethnic composition in Basanta
(From CFUG's record, and B/C is Brahman and Chhetri)

The users of Basanta-hariyali CF have diverse main income sources (Figure 3.6), which are supplemented from additional sources. It is, however, clear that the majority of users rely on income from jobs available in their locality.

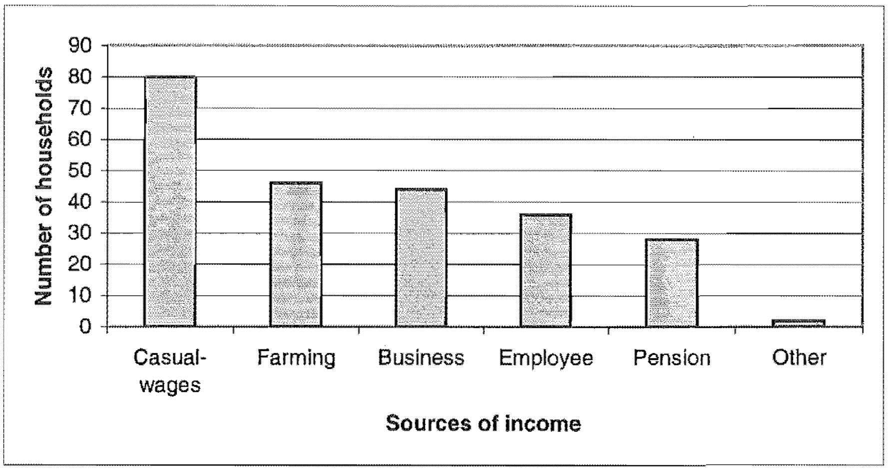

Figure 3.6: Major sources of income in Basanta
(From CFUG record)

Management history

As the forest was a part of a government forest, the district forest office was responsible for its management. Management included regular visits by forestry field staff. The forest, being close to the district headquarters, was under severe pressure from increasing timber demands for infrastructure development and urbanization. The forestry office issued timber permits for this forest. Timber harvested under these permits, and smuggling to feed the increasing market, rapidly changed the forest condition to open and scrubby, and left only scattered deformed trees throughout the forest. Local people correlate the intensity of destruction with political events, such as elections, movements, and the referendum of 1980. These activities moved the forest far from the village, shown by the continuum from bare land, scrubby bushes of *Lantana camera*, scattered deformed trees, and dense forest.

The bare land close to the village was fenced and planted with *Dalbergia sissoo* and *Leucaena leucocephala* with the support of the district forest office. Additionally, a local person was employed as watcher (paid by forestry office) to protect the plantation, but the destruction in the other parts of the forest went unchecked. The forest was so devastated that local people faced hardships to acquire forest products for their subsistence. As a result, local people formed a protection committee in 1985 and initiated protection activities through patrolling of the forest by a locally employed guard (the guard was paid by a contribution, mainly grain, from each household). Several changes were made to the constituents of the committee, and political interventions were also encountered several times; however, the protection was continued.

Forest management was institutionalized with the approval of an operational plan (1996/97 to 2001/2) in July 1996 by the Dang district forest office (BHCFUG, 1996), which was prepared by users with the help of forestry field staff. The operational plan set the following objectives:

- Effective forest management for a sustainable supply of forest products to meet the users' demands;
- Contribution to environmental conservation;
- Planning and implementing forestry development works;
- Forest stand improvement;
- Water sources conservation and soil erosion control;
- Protection of fauna;
- Raising awareness among the users of the ethic of voluntary contribution towards community forestry development.

Although the focus of management is on improvement of the sal stand, users are aware of many non-timber forest products from Basanta-hariyali community forest (see Chapter VII and Appendices). Non-timber forest products include compost, fodder, medicinal items, agricultural implements, fibre, ornamental items, utensils, food and food preservatives. Management of the forest for medicinal plants and other non-timber forest products is a great concern of the users. Protection is the major activity of forest management, with activities such as thinning, singling, pruning and cleaning prescribed for forest stand improvement. The forest is divided into four compartments (divided by rivulets) and prescriptions are specified for each compartment. Pruning was prescribed for compartment 'A' (i.e., southern most compartment) in the year 1997/98, and all the silvicultural activities are scheduled for winter i.e., November to February (forest legislation has such provision).

3.2.2 Rapti Community forest

Rapti community forest is in Lalmatiya VDC, and is located near Bhalubang town on the Mahendra (East-West) Highway. This forest totals 904 ha, and is extended over plains near Bhalubang and in the hills near Bagasoti village. Elevation ranges from 260 m to 750 m above sea level. The forest and users settlements constitute the watershed for Bagasoti rivulet that finally meets Rapti River.

Rapti community forest falls mainly under dry siwalik sal forest type (Champion and Seth, 1968), and bhabar sal forest (Stainton, 1972). Sal is the dominant species and other species are present in lower layers in the lower elevation of the forests. Small patches of mixed tropical hardwood are also present at high elevation and on northern aspects. The forests consist of newly generated secondary forest stands and over-mature patches. A small patch of 14 ha close to Bhalubang is planted with *Dalbergia sissoo* and other broad-leaved species.

Users are settled on the periphery and in the middle of the forests, and the main settlements are Bhalubang, Chaite, Nadital, and Bagasoti (Figure 3.7). Historically the area was sparsely populated, but population has increased recently due to heavy migration from the nearby hills.

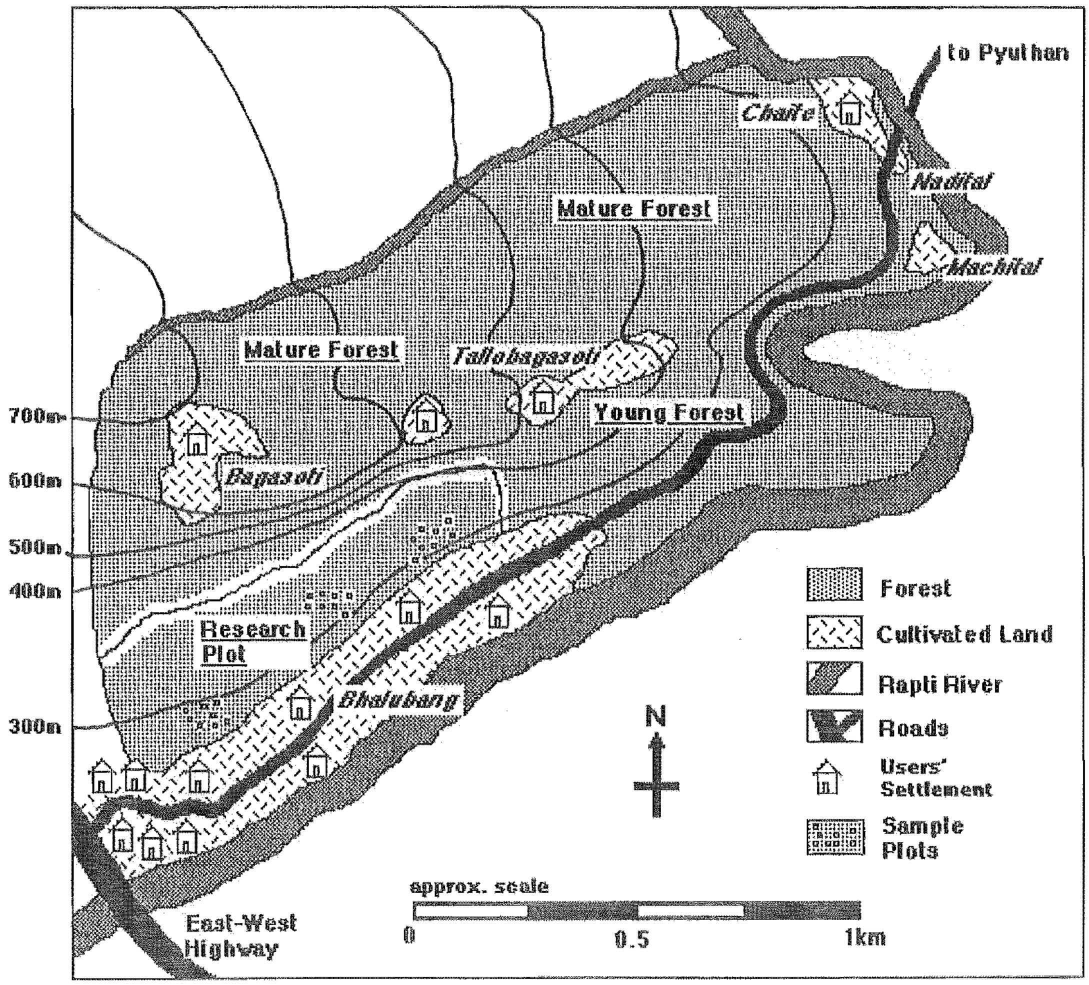

Figure 3.7: Rapti community forest

The users group is composed of several ethnic and caste groups (Figure 3.8), with various socio-economic subgroups in each group. The main income sources for the users are presented in Figure 3.9; however, they do depend on more than one income source. My association with the users during fieldwork gave me an impression that the majority of users have difficulties earning sufficient income to meet their needs.

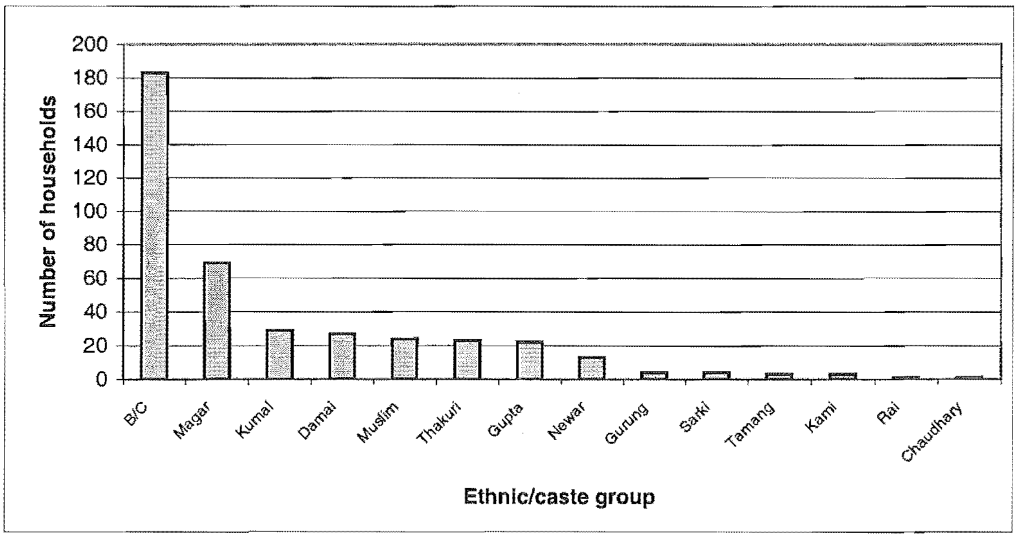

Figure 3.8: Ethnic composition in Rapti

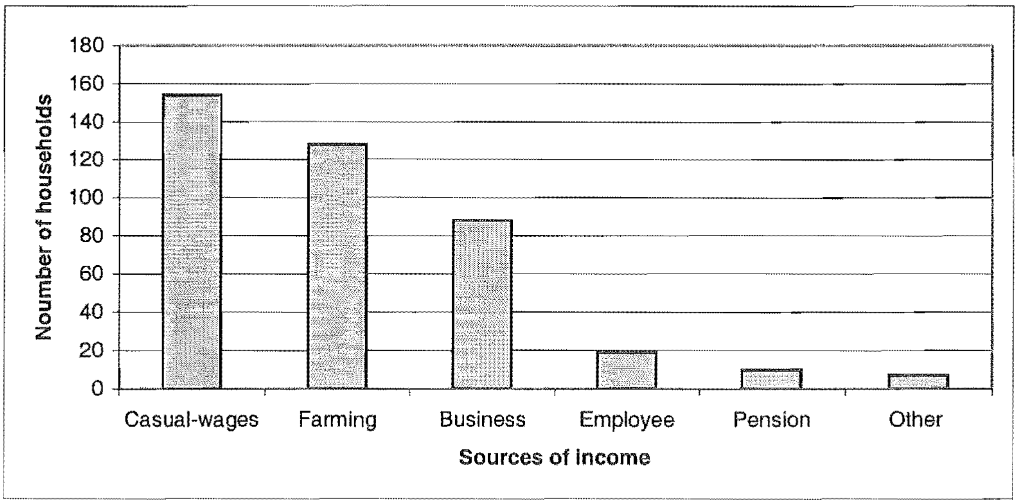

Figure 3.9: Major sources of users' income in Rapti

Management history

The Rapti forest was under the jurisdiction of the district forest office, and management only included protection. As the protection efforts of the district forest authority were ineffective, the forest deteriorated. Construction of the east-west highway, and later the construction of Bhalubang-Pyuthan Road, resulted in serious degradation and left only the malformed and commercially less valuable trees in the forest. Furthermore, around the Bhalubang settlements no trees at all were left, and only scrubby bushes of *Lantana camera* were present as evidence of the degraded forests. However, forests in the higher area and far from Bhalubang were relatively little affected by these roads and settlements. The degradation of adjoining forests compelled local people to consider protection and management, and they responded by forming protection committees.

Protection of regenerating forest areas has been effective since 1990. Although efforts were initiated to manage the forest as a community forest since 1992, the management plan was approved and handed-over only in 1996. The management plan has the following objectives (RCFUG, 1996):

- Management of the forest with users' participation;
- Sustainable supply of forest products through effective protection, development, improvement and management of the forest;
- Raise income level of local users through forest resources;
- Raise awareness of the forest and the environment and achieve people's participation;
- Improve forest condition through scientific forest management;
- Develop the forest as a demonstration of forest protection and management.

The management plan has prescribed silvicultural activities such as thinning, pruning, cleaning, weeding and protection. Users see the forest as a source of more than timber (see Chapter VII and Appendices). The forest has been the source for compost, fodder, implements and medicinal plants, but management has concentrated on protection, focussing on trees. However, the management plan has identified the potential of many non-timber forest products from Rapti community forest, dividing the forest into four compartments.

3.3 Compartment selection for experiments

The research was experimental, with controlled treatments and intensive measurements, for the following reasons (Adler and Synnott, 1992):

- although local people are lopping leaves /foliage and collecting ground-litter from sal forest, these practices have not been regularised as management practice;
- time available for the research was strictly limited.

Users' willingness to follow experimental protocols was essential to achieve the research. Once the CFs were selected, discussions were held with users to verify their willingness to allocate an area for research. Several formal and informal contacts with different socio-economic groups within the CFUG resulted in the decision to alienate a compartment for the experiment, which was different from samples drawn at random from a large population (Mead *et al.*, 1993).

Compartments for experimental plots were selected after a series of discussions and visits to the forests. One compartment of 5 ha (approximately) in each research site was selected based upon the following factors:

- Compartments were already allocated to research in operational plans;
- Compartments were not scheduled for immediate harvesting;
- The allocated compartment would not reduce users' flexibility for other activities;
- The compartment ideally would be a small area so that maintenance would be easier;
- Stands in the early developmental stage as far as possible.

Accordingly, research compartments were selected in both forests. In Basanta, research plots are confined to 'A' compartment (southernmost compartment in Figure 3.4), in which a 5 ha sub-compartment, a hillock, was allocated for continuing silvicultural research on young even-aged sal forests (Figure 3.10). The hillock comprised of two slopes (eastern and western) and a flat area on the top. The slope ranges from 0 to 30%.

Figure 3.10: Forest stand in experimental plot Basanta

In Rapti, a flat section of 5 ha in block 'A' (the compartment adjoining to Bhalubang settlement) was set aside for silvicultural research; forest in this part consisted of young, even-aged (with sparsely scattered a few residual old trees) trees (see Figure 3.7). Based on the distance from the main settlement area, the section is further divided into three parts. Stand characteristics are based on the information from the research section only (Figure 3.11).

Figure 3.11: Forest structure at experimental plot Rapti

3.4 Experimental design

As elsewhere (section 1.2), users in Basanta and Rapti were using sal forests for fodder and litter, too, which was indicated in their respective operational plans. The research questions (raised from field experience) posed earlier (section 1.3) were very relevant (users expressions and also documented in respective operational plans) in context of Basanta and Rapti. Although treatments were designed from relevant literature review while developing research proposal, discussions with the users confirmed treatment levels based upon local lopping and litter collection practices.

a) Treatments

The main experiment was laid out as a 4 x 2 factorial with lopping intensity at four levels and ground litter at two.

Local users normally lop trees from the bottom up, so the four levels of lopping intensity were:

- No lopping

- Light lopping (lower 40% of tree height)
- Medium lopping (lower 60% of tree height)
- Heavy lopping (lower 80% of tree height)

The second factor was the ground litter at two levels:

- No removal (dead and lopped material retained in the ground)
- Complete removal of dead and lopped plant material from the ground

b) Replications

Eight treatments with three replications were laid out at each of two sites in November, 1997.

c) Plot shape and size

Because of the numerous small trees per unit area at the research sites, it was felt that a plot of 50 m^2 would generate sufficient information for the research objectives.

Circular plots were preferred over rectangular, triangular, or hexagonal on the following grounds:

- Circular plots are easier to lay in the forest, as in the case of rectangular plots, right angles are generally quite difficult to achieve accurately without sophisticated equipment;
- Circular plots are easier to maintain, as only one permanent marker would serve instead of three, four, or more;
- It is easier for slope correction, only a tape held horizontally from the central point would be sufficient for smaller plots;
- As a circular plot has lower perimeter/area ratio than a rectangular plot, edge bias is decreased.

d) Blocking

Research compartments were visited and location, slope, aspect and proximity from settlement were recorded. To reduce internal variation, each compartment was divided into three blocks of approximately equal area. Blocking in Basanta-hariyali was based mainly on aspect and distance from settlements. In Rapti it was based on the distance from the concentrated settlement, with blocks separated by creeks.

e) Plot centre

Centre points for individual plots in each block were selected after travelling the block several times. At this stage, portions of stands with too many disturbances, such as trails, big pits, stumps, and shadows from old trees, were visually assessed and excluded from selection. Also, very steep slopes were avoided. Plots were laid in areas of similar stocking, topography and soils (visual assessment) within the allocated blocks, with a minimum of mean stand height buffer to isolate plots (Ellis and Dunlop, 1991). Trees were then marked for the plot centres.

Altogether 15 such points were identified at each block in both sites. Eight circular plots in each block with radius of 3.99 m were established, selecting randomly from the marked plot centres.

Later, it was considered necessary to test whether or not the process of selecting plot centres during initial measurement was biased and to gauge how representative the plots were of the compartments and the forest type more generally. Measuring of new plots was to test whether the information from initial plots and new plots came from the same population, through conducting t test and ANOVA.

Additional plots that were selected randomly were established and means compared with the means of the initial plots. Maps were prepared for each of the research sites, and they were transferred to graph-sheets with 0.1 cm grid line. Co-ordinates were listed using a random number table, and these co-ordinates were drawn on the respective maps. Distance and bearing from a reference point were noted; these points were located in the field by traversing with hip-tape and silva-compass. Once the points were located, assessments were made as to whether the points qualified, depending upon the disturbances. Accordingly, six additional plots were established in the research compartment in each site, which was not disturbed since the establishment of the experimental plots in 1997. Qualified points were marked for plot centre, and variables (dbh, root collar diameter and tree height) were recorded in the same way as for the first plots. Establishment of additional plots met the requirement for the Dunnett test to compare initial mean and other treatment mean (Zar, 1974) in future, as the experimental plots are intended to be maintained beyond my study.

Final measurements from initial plots and measurements from random plots were compared by performing analysis of variance with GLM procedure of SAS (SAS, 1990).

f) Growth variables

"Stand growth or productivity refers to the changes in total volumes of all plants or parts of plants" (Oliver and Larson, 1996:1). Tree growth is a good index of forest productivity and health in any forest site. Variables such as height, basal area, volume and biomass are important determinants of tree growth depending upon the objectives of the study. Height and diameter growth are commonly used as elements of tree growth in forest mensuration (Husch *et al.*, 1982). Current and future expectations of forest outputs and values are far different from those of the past; however, stem growth was judged to be the best indicator of total forest outputs, including foliage. As the present study aimed at assessing the effects on stem growth from lopping, tree height and dbh were used to assess treatment effects. Basal area was used to delineate treatment effects more precisely; volume reflected the combined effects on dbh and height.

Considering the objective of community forest management in general, and the management objectives of both (Basanta and Rapti) community forests in particular, species composition of species at different layers (including ground flora) were found very important to meet the demand for multiple products. Assessment of treatment effects on regeneration of all life forms became necessary for sustainable management of community forests. Accordingly, effects on regeneration were considered in the study.

3.5 Initial measurement of variables

Initial measurements were made between November, 1997 and February, 1998.

a) Stand measurements

The central tree, usually a dominant, was marked with white enamel paint. A person held the tape at the central tree, and another held the other end of the tape at each measure tree, and moved clockwise. Distance (with a tape) and azimuth (with SILVA compass) from the centre to each tree within the 3.99 m plot radius were measured. Each measured tree was numbered with blue enamel paint. The last tree measured in all the plots was the central one, so the central tree number reflected the number of trees in the particular plot.

All trees over 1 m high in the plot were recorded. However, sometimes trees under 1 m were also recorded if the species was not previously recorded. The following variables were measured:

- Species recorded by their local name;

- Diameter at breast height (dbh) of all trees above 1.37 m high was measured with a diameter tape, and sometimes with vernier callipers when the stem was very small.

- A wooden rod of 1.37 m was used to determine the point for dbh measurement. Measurements were always done from the uphill side of the tree (Husch *et al.*, 1982; Philip, 1994). Slope correction was made instantaneously by stepping the tape (Adler and Synnott, 1992), and additionally by use of string and rock whenever necessary[3].

- Collar diameter of trees between 1 m and 1.37 m high was measured with vernier callipers.

- Total height for each tree was measured with a scaled bamboo (Figure 3.1);

  A clinometer was used initially for height measurements. However, a 5 m long dry and straight bamboo was marked at each cm with enamel and was used to measure the total height of the tree, as it was convenient and fast inside the forest (Figure 3.12). It was also found more accurate than a clinometer, which was not accurate for small trees, and involved frequent corrections on sloping ground.

- In the case of bent trees, length of the stem was measured along the stem and minor bends were neglected.

- Multiple stems forked below 1.37 m and clearly showing as separate stems at breast height were recorded separately. But when the stems looked like branches from a stem, only the tallest one was measured, though the forking was below the 1.37 m. The same process was followed at both sites for both measurements, so that the same stems were measured in 1997 and 1998.

[3] A small rock was tied in a string, and the string was tied to a long, straight pole. Whenever it was necessary, the pole was held horizontally from the centre tree, and the rock pointed the position to the ground. The horizontal distance was then measured along the pole.

Figure 3.12: Height measuring pole

a) Regeneration census

Smaller plots for regeneration enumeration were established within the treatment plots. Five regeneration plots of 1 m^2 were established in each 50 m^2 plot, one in each quadrant and one in the centre (Figure 3.13).

A square wooden frame of 1 m^2 interior area, with all sides detachable, was made locally for conducting the regeneration census. The wooden frame was placed 2 m from the centre diagonally along 45^0, 135^0, 225^0, and 315^0 bearings from plot centre. A central plot was also established by laying the four corners of the frame at 45^0, 135^0, 225^0, and 315^0 bearings. All plants (excluding the measured trees) and ramets with leaves present inside the frame at the time of counting were recorded.

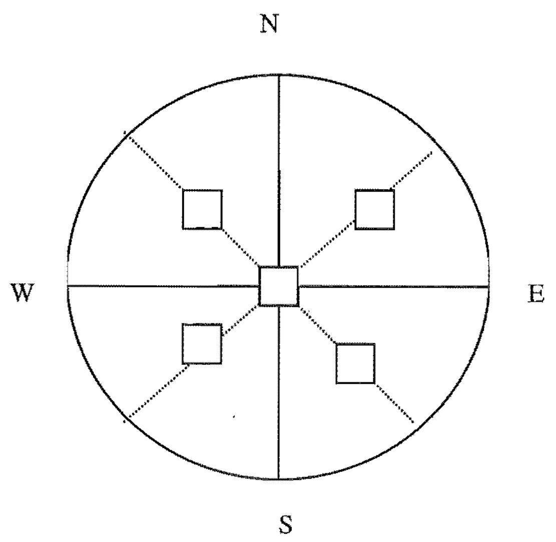

Figure 3.13: Locations of regeneration plots in experimental plot

When trees or other objects interfered with placing the frame, placement was adjusted slightly always in the clockwise direction. To maintain the area and to locate the same area in future measurements, wooden pegs were fixed in two corners of the frame.

3.6 Treatment allocation

Treatments were systematically allocated to plots with a random start. Trees were lopped immediately following dbh and height measurements and regeneration counts. Branches were lopped with a local sickle and khukuri (sword), climbing trees whenever required. Ground litter (only dry) cleaning treatments were done after completing tree measurements and regeneration counts.

3.7 Second measurements of variables

Second measurements of diameter and height, and counts of regeneration were made between November, 1998 and February, 1999.

a) Tree growth

Diameter at breast height (or root collar diameter for trees > 1 m and < 1.37 m tall) and tree height were measured in the same manner as the initial measurements. The following were encountered in the field, and dealt with accordingly:

- Trees achieving 1 m height since the last measurement were recorded as ingrowth.
- Dead trees were indicated in the inventory sheet.
- Broken or cut trees were noted in remarks and measured if the stump was alive and equal to or greater than 1 m height.

b) Identification of plants

Local plant names were listed in the forest, with some plants known locally by more than one name. Sometimes, more than one local name was noted among the users. All names were recorded. References (Howland and Howland, 1984; Polunin and Stainton, 1984; Stainton, 1988; Storrs and Storrs, 1990; Gurung, 1991; Shrestha, 1998) were consulted for Latin names, and later a botanist visited the Basanta-hariyali community forest to identify plants by their scientific names. The majority of tree species were thus identified.

Specimens of unidentified plants were collected from outside the plot and taken to the central herbarium in Kathmandu for identification. Most specimens were sterile, hampering identification. Arrangements were also made to collect specimens when they flowered to allow more accurate identification.

3.8 Data analysis

Growth data

Trees less than one metre high were recorded during the first measurements for species listing purpose if they did not occur as taller individuals, but they were not considered further apart from listing in the flora. Trees of one metre high and taller were categorised as either:

- Diameter at breast height (dbh) category trees (taller than 1.37 m) or
- Root-collar diameter category (trees between 1 m and 1.37 m high)

Basal area and stem volume were calculated from diameter at breast height (d) in centimetres and tree height (h) in metres using the following formula:

- Basal area (BA) in $cm^2 = \pi(d/2)^2$ (Husch *et al.*, 1982:86)
- Stem volume (v) with bark in $(decimetre)^3$;

  $Ln(v) = a + b*Ln(d) + c*Ln(h)$, where Ln is natural logarithm. Values of a, b and c are (-2.4554), (1.9026) and (0.8352) respectively for *Shorea robusta* (Sharma and Pukkala, 1990). This single species constitutes 79 and 68 percent of trees measured in 1997 in Basanta-hariyali and Rapti community forests, respectively. No other single species constitutes a significant proportion of the stand.

  Stem volume in $m^3 = v/1000$.

Cross-sectional area at root-collar and stem volume of trees between and 1 m and 1.37 m high were similarly calculated from root-collar diameter and height.

Diameter and height records were obtained from direct measurement (Steel and Torrie, 1980; Sokal and Rohlf, 1987; Mead *et al.*, 1993); these and derived variables, such as plot basal area and volume, were tested for normality using the Univariate procedure of SAS (SAS, 1990).

- Growth data were analysed with the following procedures:

To remove the effects of the initial size of trees, an analysis of covariance (ANCOVA) using SAS GLM procedure (SAS, 1990) was done on the increments of diameter, height, basal area and volume (tree and plot level), with the first measurements of the same variable as covariate. Although in some cases, the initial, i.e., 1997, dimensions were significantly different, the covariates were not significant in analyses of increments. When the covariate was not significant, the covariate was removed from the model, and not shown in the results. Tests for treatment effects were conducted through analysis of variance (ANOVA) and general linear modelling (GLM) procedures (SAS, 1990).

Ingrowth had only one reading, recorded in 1998/99. Analyses of treatment effects on ingrowth and mortality frequencies were performed with categorical data modelling (CATMOD) procedures (SAS, 1990). Analysis of variance was conducted using the GLM procedure on the stand basal area and stem volume of ingrowth by treatment. Basal area and volume of dead trees were calculated from the record of 1997/98 readings, and analysis of variance was performed using the GLM procedure.

The means (adjusted means in case of ANCOVA) of all main effects were compared by Tukey test with a confidence level of $p \leq 0.05$.

Levels of analyses

Data were analysed on three levels: tree, plot, and dominant trees.

- Tree-level analysis

Tree-level analyses were based on the average tree values (dbh, height, basal area and volume) calculated for each plot, i.e. the sum of all trees in a plot divided by the number of trees in that plot.

- Plot-level analysis

Plot-level analyses were based on the sum of all trees in a plot, i.e., 50 m^2. Mean plot values were based on the sum of all plot values within a site, block or treatment divided by the number of plots in that site, block or treatment. Per hectare values are calculated by multiplying plot values by 200.

- Additional analysis of growth of dominant trees

One-hundred trees ha^{-1} has been recommended for selecting dominant trees in a even-aged forest (Husch *et al.*, 1982; Philip, 1994), which are mainly managed for timber production. The management objectives of Basanta and Rapti are beyond timber, and are aimed at producing multiple products. Considering the objectives and forest situation (species, stocking and age), 2000 trees ha^{-1} (or 10 trees / plot) were selected in the present research.

The ten largest trees from the first measurement (i.e. 1997 measurement) were selected from each plot at both sites. Abnormal (broken, cut or dying) trees were excluded, and replaced by the next largest trees. The ten tallest trees from each plot were also selected similarly. The overlap between diameter and height-dominant trees for each site is shown in Table 3.2. Growth data of all these trees were analysed for largest and tallest tree groups separately for both forests, and treatment effects tested on three subsets of the data.

Table 3.2: Frequency of plots with overlapping trees

Forest	Frequency of plots with overlapped number of trees						Total plots
	5	6	7	8	9	10	
Basanta	3	5	7	6	2	1	24
Rapti	3	6	9	6			24
Total	6	11	16	12	2	1	48

Regeneration data

Records from the regeneration census were tabulated in a spreadsheet (Excel) at quadrat level, noting species, life-form, and frequency. Summaries were created as pivot tables in the Excel worksheet.

Frequencies were summed by life form - fern, fungi, grass, herb, liana, palm, shrub and tree. Changes in frequencies were calculated by subtracting the frequency at the first census (1997) from that at the second census (1998), except in the case of shrubs in Basanta. In this case (shrubs in Basanta), changes in frequencies were calculated by subtracting the frequency at the second census (1998) from that at the first census (1997), as the sums of frequencies from the second census were less than those of the first census in 22 out of 24 plots. As the dependent (change in frequency) and independent (species, life form) variables were discrete and categorical, respectively, analyses were performed using maximum-likelihood estimation of parameters with categorical data modelling (CATMOD) procedure (SAS, 1990). The procedure analysed dependent variables (frequency) with a log-linear model, which included the main effects and the interactions of independent variables.

Analyses of regeneration frequencies were performed with a complete (all main treatments and interactions) model, and subsequently in different levels by reducing variables in the model. A Chi-square test was performed for each effect. The likelihood ratio statistic, an appropriate goodness-of-fit test for the model, compares the specified model with the unrestricted model (SAS, 1990). Contrast statements, as included in the CATMOD procedure, were used to analyse the contrast between treatments.

Initially all variables were included in the model in this order: site, block, lopping, and litter. Because the site effect was highly significant, separate analyses were performed for each site. The difference between the two sites was further evaluated by comparing site and treatment interaction for total changes in frequency. The result was highly significant. Site-specific analysis was considered more appropriate to assess the main and interaction effects of lopping and ground-litter, and accordingly site-specific analyses were performed.

Zero and negative frequencies were replaced by a very small positive number (i.e.1E-20) to meet the requirements for the CATMOD procedure (SAS, 1990). In some cases (explained in the particular section), where the model either indicated error (one or more redundant or restricted parameters) or stopped processing, at least one variable from the model was deleted from the model for further analysis.

In addition to two-way frequency tables, χ^2 and p values are given for lopping and litter removal treatments. Whenever interactions are significant at the 5% level and main effects are larger than interactions, row and column differences are presented as percent change.

3.9 Indigenous knowledge

3.9.1 Information collection

Information on indigenous knowledge of multiple products and ethnosilviculture was collected during two rounds of fieldwork - October 1997-February 1998 and November 1998-February 1999. Approaches and methods used to gather this information are presented in Figure 3.14. Periods of establishing research plots and two measurements were good opportunity for researcher's observation and exploring such information. Unstructured observations and discussions were the medium for learning about the social and biophysical environments of the FUGs. A team of about 15 users daily provided frequent interactions, and helped select key informants on indigenous knowledge of multiple-products and ethnosilviculture of sal forests.

Studies in Nepal and elsewhere (Schroeder, 1985; Rusten, 1989; Hobley, 1990; Malla, 1992; Gakou *et al.*, 1994; Thapa, 1994; Olson, 1999; Rastogi, 1999) have indicated that variables such as ethnicity, wealth, and elite status are likely to influence knowledge held by any particular individual or group of people, and additionally gender and age influence across all these variables. Both the users groups have similar ethnicity and occupational categories (see Chapter 4 for detail of all categories). Ranking on the basis of wealth was not simple and easy within the study period; however, landholding class gave some indication of wealth. Elite people were found to be either holding positions in political and social organisations or employed elsewhere.

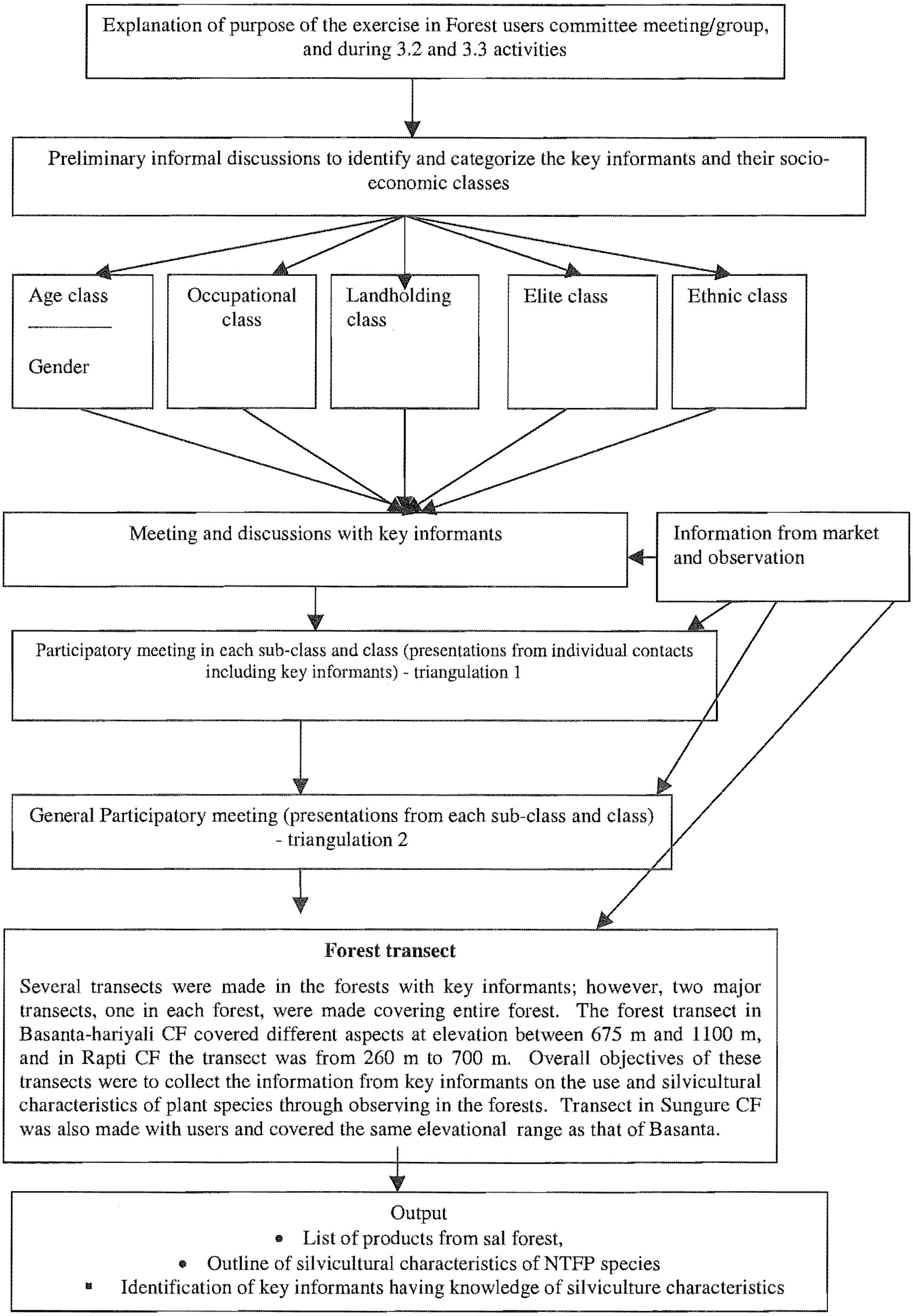

Figure 3.14: Sequence of activities for studying indigenous knowledge

Each forest users group committee initially selected a few people (15 in Basanta and 10 in Rapti) as key informants for the research. Later, with several interactions with key informants and other users in the field, a few more people were identified as informants. Fifty-one (26 women and 25 men) in Basanta, and 41 (18 women and 23 men) in Rapti were identified as key informants for the study. Although key informants were selected based upon their knowledge of (known among the users) and affiliation with forests, an effort was made to represent users from all broad socio-economic categories as featured in the FUGs (Table 3.3). Ethnic groups with small numbers were broadly grouped as: occupational (Kami, Sarki, Damai and Sunar), indigenous (Chaudhary and Kumal), other hill people (Thakuri, Gurung, Newar, Badi, Rai, Tamang, and Muslim), and people from Tarai (Gupta). Representation based upon age and gender of informants was also emphasised. Thus, the users rather than the researchers selected key informants following several discussions on the objectives of the research.

Table 3.3: List of categories for each variable

Ethnic group	**Occupational group**	**Landholding group**	**Elite group**
1. Magar	1. Casual labour	1. No land	1. Common*
2. Brahman/Chetri (B/C)	2. Farming	2. Land <.25 ha	2. Elite*
3. Occupational	3. Business*	3. Land >.25 ha	
4. Indigenous	4. Employee*		
5. Other hill people	5. Pensioner*		
6. People from Tarai*	6. Other*		

* These groups were either merged in other groups or dropped in the analysis.

Once the key informants were identified, FUG helped get these people deputed to the fieldwork. This facilitated the exploration of knowledge while measuring trees. Recording was always maintained, and at the same time background (age, gender, ethnicity, landholdings and elite status) of key informants was noted. This process and individual discussion with the key informants resulted in a list of plant products from sal forest and ethnosilviculture from local users' perspectives. Unstructured interviews that included questioning, discussion and listening among key informants were made very informal but focussing on the products and ethnosilviculture. Questions and responses were open-ended, and sometimes as expressions of experiences and tales. All this information was recorded in notebooks and audiocassette depending upon the location of the meeting (usually notebooks were used in the forest, and both notebooks and audiocassette in village).

Key informants were asked open-ended questions about the use and silvicultural characteristics of plant species encountered in the forest. As the research aimed at identifying products and silvicultural characteristics known to different sectors of users, key informants were not asked about specific products. Socio-economic background of the key informant who responded about the forest product or silvicultural characteristics was also recorded to enable identification of the groups of users holding such knowledge. The reason for not directing key informants to discuss any specific issue was to explore their status of knowledge by letting them express voluntarily. The first expression on any species may imply either importance of that species to interviewees or confidence of the knowledge on them.

The findings from the key informants were then discussed in small meetings with specific groups of people first and then in the larger groups. These meetings were primarily for verifying the earlier information (triangulation). Later, additional forest transects with key informants further helped to explain the use and silvicultural aspects of the particular species.

Thus, information from key informants was collected mainly through open-ended questions and subsequent discussions at experimental plots, villages, CFUG offices and transects. In some instances, interactions among the key informants also yielded valuable information.

General information on the sal forest, products and their uses were collected in the first period of fieldwork, whereas silvicultural aspects such as flowering, fruiting, seed characteristics, seed dispersion, propagation nature, etc were focussed upon in the second period. The information collected in the first fieldwork was further verified during the second fieldwork.

Each fieldwork period was split between two forests. Instead of completing work in one forest in one stay, the work was done in a number of stays in both forests. This process of time-splitting over two fieldwork periods resulted in very effective information collection. Some of the information missed in one forest was learnt later while working in another forest, and was collected in the following visit.

After partial review of information from the first fieldwork, it was felt worth assessing the context from a third forest. During the second fieldwork, additional information on the same aspects were collected from Sugure CFUG in Dang, which was found involved in managing a similar sal forest. Information was collected from six women and thirteen men who were nominated by users in Sugure.

CFUGs deputed users for assisting research activities (measuring, lopping, litter removal and participating as key informants), and also made arrangements for protection of research plots.

Reciprocally, the researcher provided financial support to the respective CFUGs to cover these costs. Individual participants were not paid directly by the researcher.

3.9.2 Compilation and analysis

The knowledge on use and silviculture from a range of sources, such as field notes and audiocassettes were first transcribed (translated from Nepali), and stored in a MS Word table as per the column shown in Table 3.4. Later the statements were split into the simple statements indicating issues (use-related or silvicultural) dealt with by the statement, and also the respondents were categorised into appropriate class depending upon their location, ethnicity, occupation, land holding, age and sex (Table 3.5).

Table 3.4: Complex statement (from direct transcription)

Species	Statement	Respondent	FUG
Maluka	Grows with sal, and rope from the bark can be sold in local market	Rammaya	RP

Table 3.5: Breakdown to simple statement

Spp	Statement	Category						
		Issue	Gender	Age	Ethnic	Occupation	Land	FUG
Maluka	Grows with sal	Associate	Female	40	Magar	Labour	0	RP
Maluka	Bark is used for rope	Use	Female	40	Magar	Labour	0	RP
Maluka	Rope can be sold	Market	Female	40	Magar	Labour	0	RP

Data were analysed using affinity diagram, interrelationship matrix and relationship matrix (Frigon and Mathews, 1997) with slight modifications (not shown in result). Subsequent sorting and resorting grouped the issues and respondents. Such processing helped change the information from the local language to general variables that became the elements of analysis and synthesis. Further analyses, mainly the test (chi-square) of association between indigenous knowledge (products and silviculture) and respondents, were conducted by SPSS procedure (Cramer, 1998; SPSS, 1999).

CHAPTER IV. BASELINE INFORMATION FROM RESEARCH SITES

Information presented here is based on the measurements of experimental plots of both forests in 1997.

4.1 Species composition

Species composition by life form is given in Table 4.1, and species representation by strata is presented in Table 4.2.

Table 4.1: Species composition

Life-form	Species (# refers code in Appendix I)		
	only in Basanta	only in Rapti	in both forests
Tree	9, 14, 21, 24, 25, 26, 28, 30, 31, 33, 38, 45, 49, 50, 51, 60, 63, 76, 81, 151, 184, 189	56, 72, 75, 83, 85, 87, 89, 92, 125, 131, 133	1, 2, 3, 4, 6, 7, 10, 11, 12, 13, 15, 16, 17, 22, 26, 32, 34, 35, 36, 37, 39, 43, 47, 52, 64, 66, 76, 81
Shrub	19, 53, 61, 140, 160, 180	70, 114	5, 8, 18, 70, 77
Liana	20, 27, 46, 54, 147, 153, 187	57, 67, 84, 88, 130	23, 29, 42, 78, 93, 106, 121
Herb	139, 141, 142, 143, 148, 152, 154, 155, 163, 165, 168, 170, 171, 172, 173, 175, 183	69, 98, 99, 102, 107, 118, 119, 123, 124, 129, 132	40, 44, 97, 103, 109, 112, 117, 122, 126, 127
Grass	145, 150, 157, 161, 162, 164, 167, 169, 179, 181	104, 105, 113, 116, 128	94, 95, 110, 111, 113
Fern	146, 182	138	134
Palm		58, 96	
Fungi		135	

Out of the 158 species recorded, 64 (41%) and 38 (24%) were present in Basanta and Rapti, respectively, and 56 (35%) were common to both forests.

Table 4.2: Species composition at different layers

Layers	Species composition (figures in parentheses are number of trees) in			
	Basanta		Rapti	
	Species	%	Species	%
Top	*Shorea robusta* (238)	99.2	*Shorea robusta* (233)	97.1
	Casia fistula (2)	0.8	*Anoegeissus latifolia* (6)	2.5
			Terminalia alata (1)	0.4
Dbh level (trees measured at breast height, i.e., 1.37 m)	*Shorea robusta*	79.2	*Shorea robusta*	67.8
	Mallotus phillippinensis	3.5	*Terminalia alata*	12.1
	Trichilia connaroides	3.2	*Lagerstroemia parviflora*	5.7
	Holoptelea integrifolia	1.6	*Buchanania latifolia*	5.3
	Clerodendron infortunatum	1.2	*Anogeissus latifolia*	2.9
	Other 43 species	11.3	*Clerodendron infortunatum*	1.7
			Other 33 species	4.5
Trees recorded in =>1 m height level	*Shorea robusta*	77.7	*Shorea robusta*	63.2
	Mallotus phillippinensis	3.4	*Terminalia alata*	12.2
	Trichilia connaroides	3.4	*Buchanania latifolia*	7.3
	Holoptelea integrifolia	1.8	*Lagerstroemia parviflora*	6.9
	Clerodendron infortunatum	1.7	*Anogeissus latifolia*	2.3
	Other 47 species	12.0	*Clerodendron infortunatum*	2.0
			Other 42 species	6.1
Ground level	Total species # 89		Total species # 74	
	Herb	30.3	Herb	38.7
	Tree	25.9	Tree	20.0
	Grass	15.7	Palm	13.2
	Liana	13.5	Grass	12.0
	Shrub	11.2	Liana	10.9
	Fern	3.4	Shrub	4.8
			Fern and fungi	0.4

Most frequent associates of sal in the two forests showed differences in species composition in three layers (top, dbh, and 1-1.37 m height levels); only *Cledendron infortunatum* was common to both forests. *Mallotus phillippinesis* in Basanta and *Terminalia alata* in Rapti were observed as the second-most-frequent species after sal.

In Basanta, species 7, 11, 13, 14, 21, 22, 24, 25, 26, 27, 28, 30, 34, 35, 36, 37, 43, 45, 47, 49, 50, 51, 54, 63, 64, and 66, were recorded in 1 m and above height level, but not found at ground level. Similarly in Rapti, species 2, 5, 11, 13, 15, 16, 17, 26, 35, 37, 39, 47, 57, 66, 75, 76, 85 and 89 were not recorded at ground level but were present in the 1 and above height level.

4.2 Growth characteristics

4.2.1 Dbh distribution

Dbh distributions are summarised in Figures 4.1 (Basanta) and 4.2 (Rapti). The dbh distributions were represented by the exponential equations, $N = 957.08e^{-0.3885d}$ (R^2=0.8124) for Basanta, and $N = 3819.9e^{-0.6867d}$ (R^2=0.9428) for Rapti, where N is the number of trees in the dbh class and d is the mean of the dbh class. Dbh ranged from less than a cm to over 12 cm; diameter classes were: 0< to 1=1, 1< to 2 =2, 2< to 3=3,...

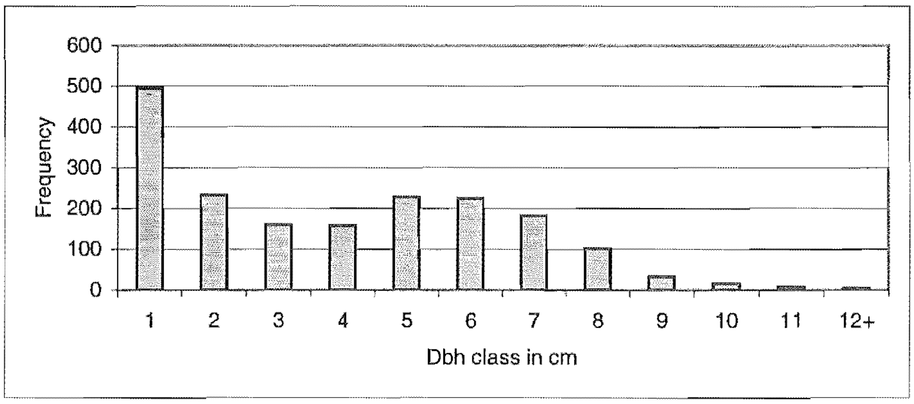

Figure 4.1: Dbh distribution in Basanta

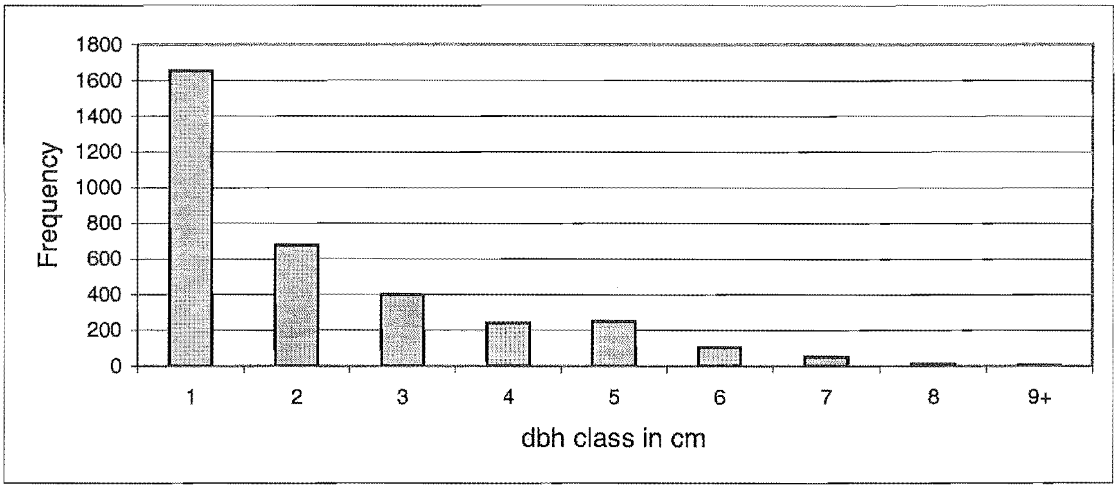

Figure 4.2: Dbh distribution in RP

4.2.2 Tree height distribution

Tree height distributions are shown in Figure 4.3 (Basanta) and 4.4 (Rapti), and fitted by the logarithmic equations N = 247.07 Ln(h) + 557.38 (R^2=0.9352) for Basanta and N = 847.38 Ln(h) + 1516.1 (R^2=0.9834) for Rapti , where N is number of trees in h height class. Height classes were: ≤1.37 to 2=2, <2 to 3=3, <3 to 4=4, ...

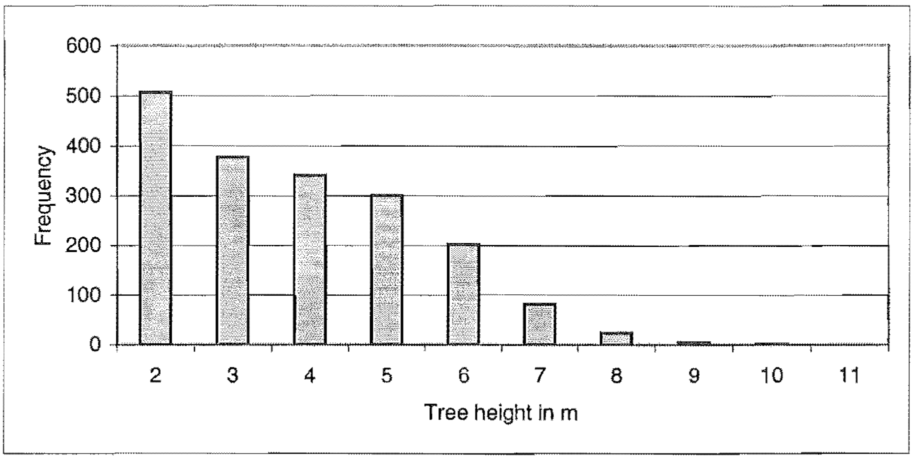

Figure 4.3: Height distribution in Basanta

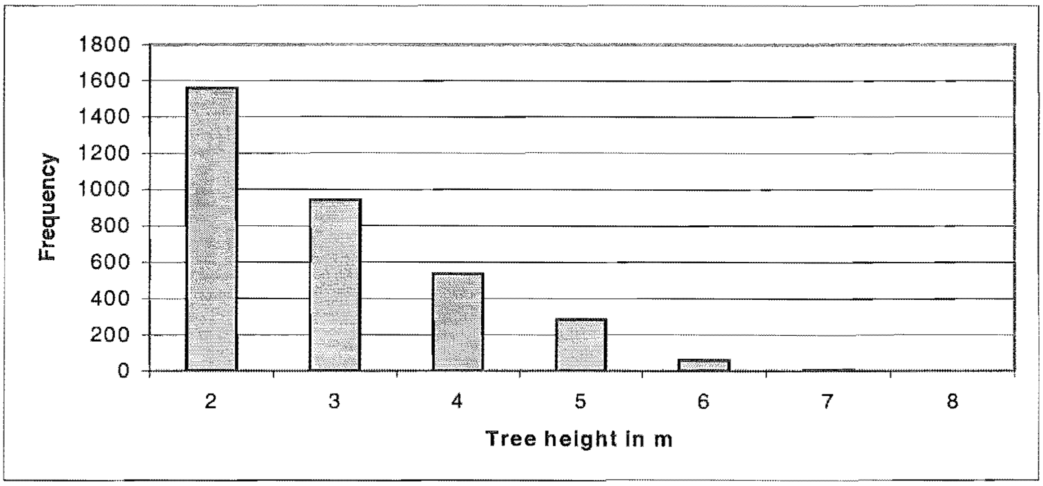

Figure 4.4: Height distribution in RP

4.2.3 Height-dbh relations

The height-diameter relations are linearly represented by equations (Figures 4.5 and 4.6):

- Height in m = 0.6067 dbh (cm) + 0.9921 (R^2 = 0.9902) for Basanta, and
- Height in m = 0.5017 dbh (cm) + 1.4146, (R^2 = 0.9766) for Rapti.

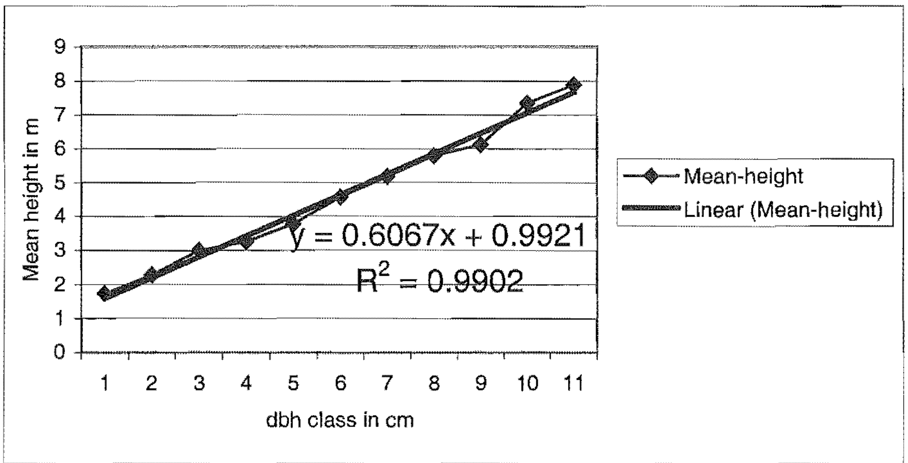

Figure 4.5: Height/dbh curve Basanta

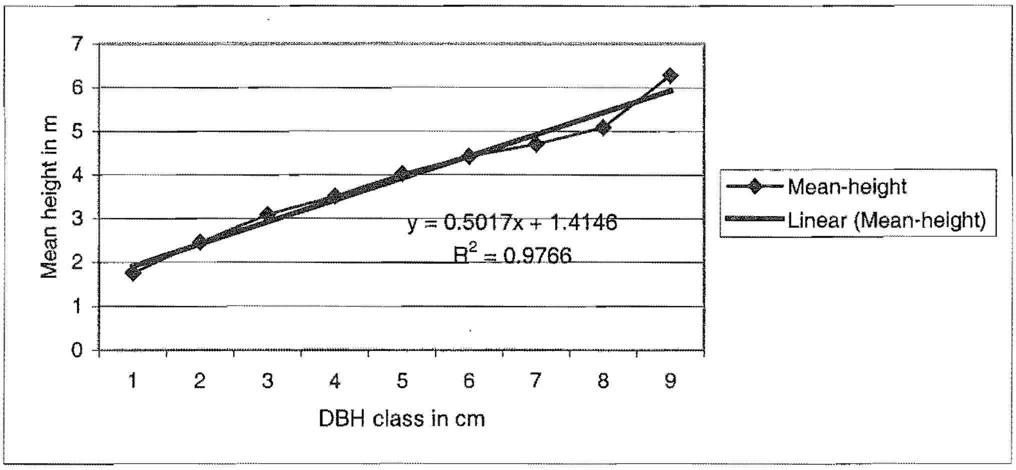

Figure 4.6: Height dbh curve Rapti

4.2.4 Crown length

Crown length, i.e., the length between the lowest live branch and the top of the tree, distribution for Basanta-hariyali is summarized in Table 4.3. About 70% (see last column) of trees retained their lowest live branch below 40 per cent of tree height (corresponding value in first column), and only 5.73 % of trees had their lowest live branch below 10% of the tree height. Thus, only 5.73% of trees had live crown exceeding 90% of bole length.

Table 4.3: Crown length, Basanta

Tree height % at lowest living branch (from bottom of tree)	Frequency	% of the total trees	Cumulative % total trees
10	**24**	**5.73**	**5.73**
20	75	17.90	23.63
30	100	23.87	47.49
40	**93**	**22.20**	**69.69 (70%)**
50	74	17.66	87.35
60	33	7.88	95.23
70	14	3.34	98.57
80	4	0.95	99.52
90	2	0.48	100.00
Greater than 90	0	0.00	100.00
Total	419	100.00	

Crown length distribution for Rapti is summarised in Table 4.4. About 71% of trees retained live branches below 40 per cent of the tree height. Only 5.98% of trees held live branches below 10% of tree height.

Table 4.4: Crown length in Rapti

Tree height % at lowest living branch (from bottom of tree)	Frequency	% of the total trees	Cumulative % total trees
10	47	5.98	5.98
20	140	17.81	23.79
30	178	22.65	46.44
40	**191**	**24.30**	**70.74**
50	133	16.92	87.66
60	53	6.74	94.40
70	28	3.56	97.96
80	10	1.27	99.23
90	5	0.64	99.87
Greater than 90	1	0.13	100.00
	786	100.00	

4.3 Variations of stand characteristics within the sites

4.3.1 Variations in dbh category

Numbers of species in the dbh category in different plots in the research compartment varied between four and 14 (Figure 4.7) in Basanta, and five and 14 in Rapti (Figure 4.8).

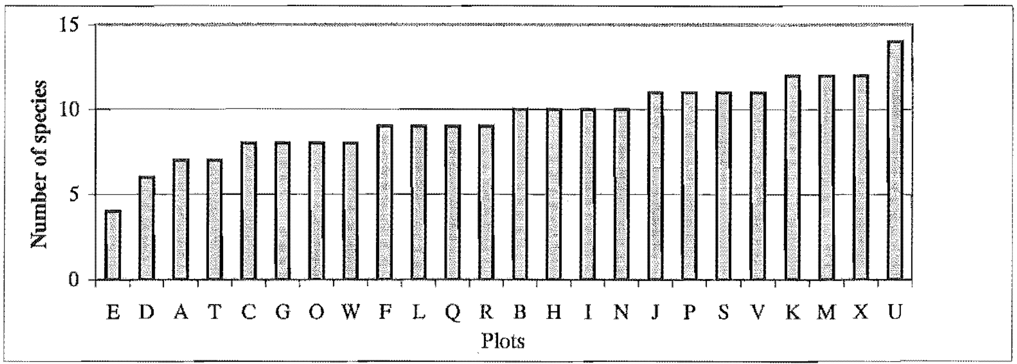

Figure 4.7: Number of species in 1.37 m and above by plot in Basanta

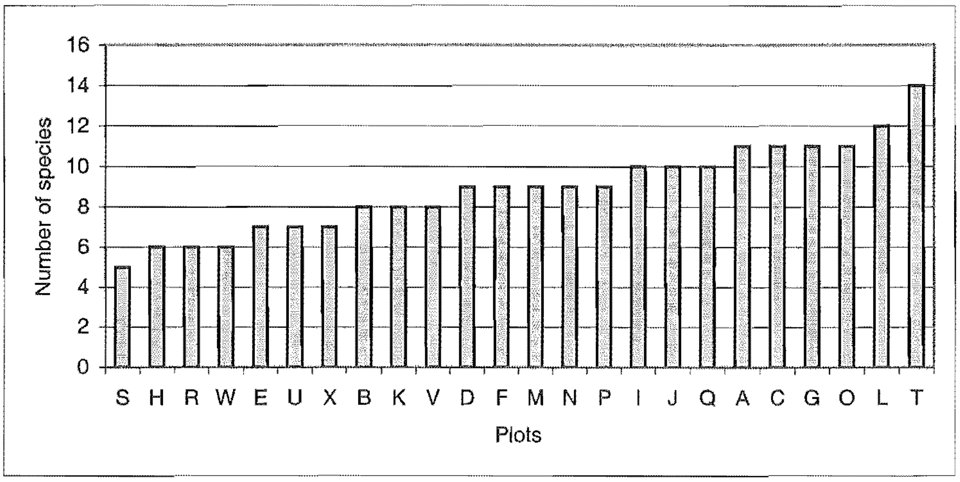

Figure 4.8: Number of species by plots in Rapti
(Taller than 1.37 m)

As both sites were divided into three blocks, block-wise growth features are presented in Tables 4.5 (Basanta) and 4.6 (Rapti).

Table 4.5: Stand characteristics of Basanta forest in 1997

Block	Trees ha^{-1}	Tree group	Mean dbh cm	Max dbh cm	Mean height m	Max height m	Basal area m^2 ha^{-1}	Volume m^3 ha^{-1}
1	14975	All trees	3.47 ±2.42	10.50	3.48±1.48	8.80	21.08	73.08
	2000	Dominant	7.03± 1.19	10.50	5.90 ±.70	8.80	7.98	32.22
2	14775	All trees	3.57 ±2.56	10.50	3.38 ±.49	8.00	22.37	75.65
	2000	Dominant	7.15 ±1.24	10.50	5.84 ±.74	8.00	8.28	33.26
3	16300	All trees	3.33 ±2.67	13.20	3.41 ±.74	10.00	22.33	86.06
	2000	Dominant	7.54 ±1.75	13.20	6.43 ±.08	10.00	9.41	41.50

Table 4.6: Stand characteristics of Rapti forest in 1997

Block	Trees ha^{-1}	Tree group	Mean dbh cm	Max dbh cm	Mean height m	Max height m	Basal area m^2 ha^{-1}	Volume m^3 ha^{-1}
1	27525	Dbh	1.67 ±1.65	10.80	2.52 ±1.01	7.00	11.92	35.51
	2000	Dominant	4.98 ±1.54	10.80	4.64± 0.73	7.00	4.23	14.90
2	28375	Dbh	1.72 ±1.69	8.80	2.51 ±1.04	6.90	12.94	38.87
	2000	Dominant	5.43 ±1.17	8.80	4.84± 0.61	6.90	4.84	17.10
3	28800	Dbh	1.76 ±1.55	7.69	2.52 ±1.01	6.85	12.47	36.00
	2000	Dominant	5.09 ±0.94	7.69	4.72± 0.59	6.85	4.21	14.56

4.3.2 Variations in ground flora

Block-wise results from the 1997 regeneration count are presented for Basanta (Figure 4.7) and Rapti (Figure 4.8).

Table 4.7: Results from regeneration count in 400 m^2 in each block Basanta

Block	Fern		Grass		Herb		Liana		Shrub		Tree		Total	
	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count
1	3	663	9	63	21	625	6	9	7	322	14	155	60	1837
2	2	351	9	71	20	627	7	20	9	189	10	61	57	1319
3	3	386	9	98	17	441	8	19	7	291	14	95	58	1330
total	3	1400	14	232	27	1693	12	48	10	802	23	311	89	4486

Table 4.8: Results from regeneration count in 400 m^2 in each block Rapti

Block	Fern		fungi		Grass		Herb		Liana		Palm		Shrub		Tree		Total	
	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count	Spp #	Count
1	1	1	0	0	7	156	17	545	9	155	1	143	4	90	13	255	52	1345
2	1	12	1	1	4	137	20	635	9	156	2	252	4	55	17	209	58	1457
3	0	0	0	0	7	139	16	214	7	83	1	81	2	28	11	256	44	801
Total	2	13	1	1	9	432	21	1394	11	394	2	476	5	173	23	720	74	3603

4.4 Stages of development

Both forests, particularly the experimental compartments, are natural regrowth forests, which were degraded due to human pressure. The interest of local people, and a very little input from the forest department, created these forests. Stocking features (Table 4.9) show the differences between the two forests. Based upon density-dependent mortality, it is expected that stocking will continue to decline until the stands reach a mean dbh of about 15 cm (Rautiainen, 1999).

Table 4.9: Various dimensions of two forests

Variables	Basanta	Rapti
Stocking (stems ha^{-1})	15,350	28,233
Mean dbh cm	3.46	1.72
Largest tree dbh cm	13.20	10.80
Mean height m	3.42	2.52
Tallest tree height m	10.00	7.00
Basal area m^2 ha^{-1}	21.93	12.44
Volume m^3 ha^{-1}	78.26	36.00

As the forest was under heavy biotic pressure for a long time, it is unclear whether trees died (as Basanta was sparser than Rapti) from self-thinning or other effects in Basanta. However, other effects such as human interference could have been related to some extent to the density-dependent-mortality, i.e. harvesting dead, dying or suppressed individuals (if that serves the purpose) is normal forestry practice in rural Nepal. Basanta-hariyali stand characteristics, including ground flora, suggest the stem exclusion stage of a multi-species single-cohort stand (Oliver and Larson, 1996). Sal dominates the stand. Average dbh is about 47% (44-50%) of dominant-trees' dbh (2000 trees ha^{-1}), and average height is 56% (53-59) of dominant-trees' height, indicating stratified canopies in the forest.

In Rapti, on top of biotic interference, self-thinning could be one of the major reasons for mortality. The stand characteristics, including ground flora, suggest the stem exclusion stage (Oliver and Larson, 1996). Average tree dbh and height are 33 and 53%, respectively, of the dominant trees, indicating stratified canopies in this forest.

Regeneration statuses for both forests are presented in Figure 4.9. Basanta, showing more species than Rapti in all life forms except in palm and fungi, showed higher number of individual ferns, herbs and shrubs than Rapti, whereas grasses, lianas and trees were more numerous in Rapti. More regeneration of understory species in Basanta may be an indication of a more advanced stage of stand development than at Rapti (Oliver and Larson, 1996).

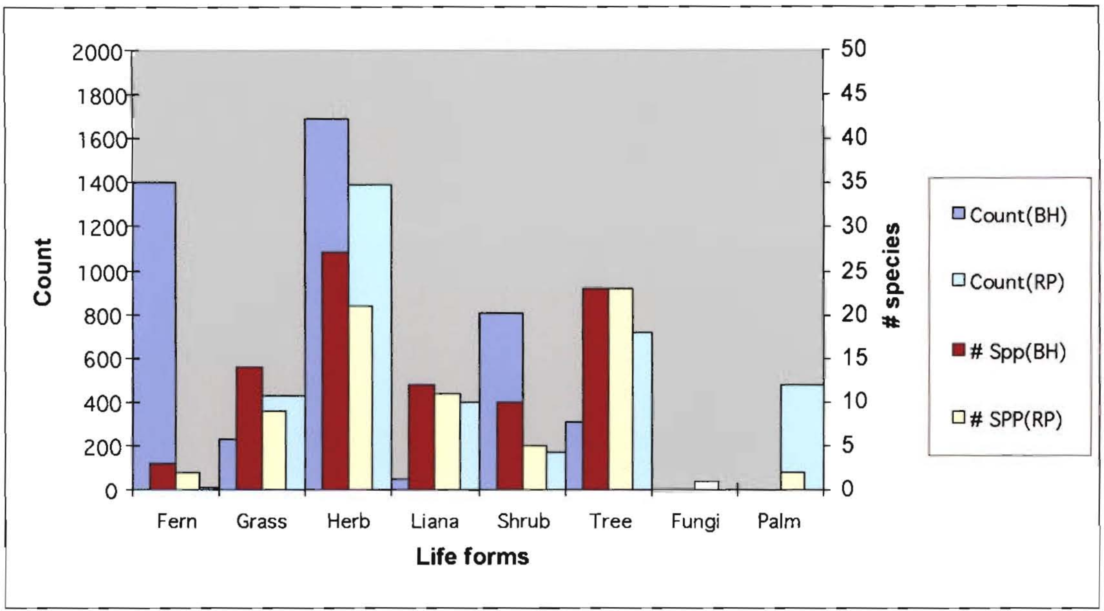

Figure 4.9: Regeneration count by species and life forms in Basanta and Rapti

In summary, the two forests differed little in species composition and customary uses. Although the two forest stands showed similarity in height/dbh curves and crown lengths, the two forests differed in stocking (Table 4). While linking stages of stand development with diameter distribution curve, both forests showed some disturbances in the past, and evidences of disturbances were also supported by management history.

In most of the life forms (except fungi and palm species) in ground level, Basanta had more species than Rapti (Figure 4.9). In a phytosociological analysis of two sal forests, Kumar *et al.* (1994) found more species in disturbed forest than protected, and this may be in line with the cases of Basanta and Rapti. Based upon the similarities and differences, the two forests may be just different stages of a continuum of stand development. Furthermore, the two sites may have different qualities, but existing information is insufficient to draw conclusions about site quality.

CHAPTER V. EFFECTS OF LOPPING AND LITTER REMOVAL ON TREE GROWTH

Out of the 70 species measured in the dbh category (greater than 1.37 m height), 25 (35.71%) were recorded at both the research sites, each from all twenty-four 50 m^2 plots. In Basanta-hariyali forest, a total of 48 and 52 species were recorded in 1997 and 1998 respectively, and 39 were recorded in both years in Rapti. Sal (*Shorea robusta)* remained the dominant tree species at both sites; however, it reduced from 79.15% to 76.99% of stems at Basanta-hariyali and from 67.85% to 67.78% at Rapti during the one-year period.

The root-collar category (tree heights 1 - 1.37 m) contained 55 species, 22 (40%) of which were present in both forests. In both measurements (1997 and 1998), sal maintained its dominance in the root-collar class, i.e. 69.55% and 67.03% of all stems in Basanta-hariyali and 48.90% and 51.77% in Rapti forest.

The study period was insufficient to draw conclusions on effects of treatments on changes in species richness. As no single species other than sal constituted a significant proportion of the sample in either forest, the analysis was based on sal and non-sal groups.

Tree growth was analyzed with respect to treatment effects on tree and plot. Besides comparing mean-tree increment in terms of dbh, basal area, tree height and stem volume, plot basal area and volume were also compared for treatment effects (main and interaction). Plot basal area and volume were calculated from 1997 records for mortality assessment, and from 1998 records for ingrowth. The following sets of data were used for tree-level and plot-level analyses:

For tree-level analysis:

i. All surviving trees;
ii. All surviving sal trees;
iii. All surviving non-sal trees;
iv. Largest 10 trees per plot; and
v. Tallest 10 trees per plot.

For plot-level analysis:

i. Plot net increment (survivor's increment + ingrowth - dead) for all trees;

ii. Plot net sal increment;

iii. Plot net non-sal increment;

iv. Increment of all survivors only (trees recorded in both 1997 and 1998 measurements);

v. Increment of sal survivors;

vi. Increment of non-sal survivors;

vii. Mortality (trees dead between 1997 and 1998 measurement);

viii. Ingrowth (trees recruited into dbh class after 1997 measurement).

In all tables in the following sections, the figures shown are mean values (for respective variables) ± standard error. Mean separations in a column are based on the Tukey test at the 5% level; means with the same letter in the respective column are not significantly different at the 5% level. In cases where covariates were significant at the 5% level, the means presented are least-square means. F values and P values are drawn from type I sums of squares except where covariates are significant; type III sum squares are used when covariates showed significance.

5.1 Initial status

Initial statuses of the forests are presented in Tables 5.1 through 5.4, based on the 1997-measurements. Although blocking was considered while establishing experimental plots, analysis of the 1997 measurements showed blocking was of no significance in either forest.

In an analysis of the initial status (1997 measurements) of different variables, the following variables were found to be significantly different at the 5% significance level when plots allocated to different lopping intensities were compared:

Basanta:

- Plot basal area and stem volume of all-tree stratum.
- Plot basal area and stem volume of sal-tree stratum.
- Mean tree dbh, basal area, volume, and plot mean basal area and volume of tallest 10 trees stratum.
- All variables of largest (dbh) 10 trees stratum.

Rapti:

- Plot basal area and volume of all-tree stratum.
- All variables of sal tree stratum;
- All variables of top 10 trees stratum; and
- All variables of largest (dbh) 10 trees.

The above results suggested that covariance analysis was indicated for comparing the effects of lopping on tree growth.

Table 5.1: Initial status of Basanta-hariyali forest at different lopping intensities

	Lopping %	Mean tree				Mean plot	
		dbh cm	basal area cm^2	height m	volume dm^3	basal area cm^2	stem volume dm^3
all spp	0	3.46±0.16	13.83±0.89	3.37±0.11	4.61±0.38	988.97±63.84b	329.76±27.52b
	40	3.62±0.12	16.24±0.83	3.49±0.09	5.81±0.45	1246.85±86.56a	445.79±39.12a
	60	3.49±0.14	15.56±1.24	3.57±0.05	5.86±0.52	1143.58±43.72ab	431.10±25.47a
	80	3.24±0.14	12.70±1.01	3.30±0.09	4.30±0.42	1017.24±32.31ab	342.93±14.51b
	F	1.25	2.39	1.75	3.10	3.86	4.42
	P	**0.3184**	**0.1046**	**0.1900**	**0.0512**	**0.0261**	**0.0162**
sal	0	3.84±0.14	15.97±0.99	3.59±0.10	5.38±0.45	949.34±53.00b	319.20±23.68b
	40	4.17±0.18	19.72±1.40	3.80±0.14	7.16±0.72	1199.40±81.31a	433.71±37.56a
	60	4.20±0.26	19.86±0.20	4.00±0.14	7.58±0.95	1107.71±41.24ab	422.00±25.66ab
	80	3.77±0.19	15.63±1.38	3.56±0.10	5.34±0.58	961.33±37.12b	325.91±14.29b
	F	1.22	2.14	2.77	2.68	4.56	5.16
	P	**0.3308**	**0.3234**	**0.0698**	**0.0759**	**0.0144**	**0.0089**
non-sal	0	1.59±0.34	3.24±1.20	2.29±0.20	0.85±0.35	39.63±16.31	10.57±4.91
	40	1.54±0.11	3.08±0.23	2.31±0.08	0.77±0.06	47.45±6.64	12.08±1.96
	60	1.35±0.19	2.74±0.85	2.23±0.08	0.72±0.25	35.87±5.98	9.10±1.53
	80	1.54±0.21	3.26±0.92	2.51±0.21	1.05±0.42	55.92±12.67	17.02±4.81
	F	0.38	0.11	0.81	0.27	0.68	0.96
	P	**0.7678**	**0.9509**	**0.5033**	**0.8453**	**0.5783**	**0.4633**
top trees	0	6.66±0.27b	35.71±2.87b	5.59±0.21	13.87±1.48b	357.14±28.68b	138.66±14.81b
	40	7.53±0.28ab	46.33±4.05ab	6.10±0.24	19.32±2.34ab	463.31±40.53ab	193.22±23.37ab
	60	7.82±0.24a	49.71±3.03a	6.56±0.26	21.97±1.89a	497.12±30.26a	219.74±18.93a
	80	6.84±0.24ab	37.66±2.73ab	5.82±0.21	15.11±1.43ab	376.64±27.26ab	151.08±14.29ab
	F	4.61	4.60	3.10	4.26	4.54	4.26
	P	**0.0138**	**0.0157**	**0.0512**	**0.0184**	**0.0146**	**0.0184**
fat trees	0	7.00±0.24b	35.06±2.70b	5.32±0.23b	14.43±1.41b	390.01±27.04b	144.29±14.17b
	40	7.99±0.31a	51.51±4.43a	5.83±0.22ab	20.58±2.42ab	515.09±26.03a	205.80±24.20ab
	60	8.02±0.19a	51.71±2.60a	6.43±0.27a	22.45±1.80a	517.11±26.03a	224.52±18.05a
	80	7.06±0.23ab	39.74±2.61ab	5.60±0.21ab	15.42±1.44ab	397.38±26.09ab	154.18±14.44ab
	F	5.37	5.35	3.83	4.65	5.18	4.65
	P	**0.0076**	**0.0089**	**0.0266**	**0.0133**	**0.0087**	**0.0133**

Table 5.2: Initial status of Basanta-hariyali at different litter treatments

	Litter	Mean tree				Mean plot	
		dbh cm	basal area cm2	height m	volume dm^3	basal area cm^2	stem volume dm^3
all spp	Retained	3.53±0.11	14.91±0.84	3.47±0.07	5.25±0.39	1073.78±39.56	376.62±19.54
	Removed	3.38±0.09	14.26±0.74	3.39±0.06	5.04±0.34	1124.54±59.64	398.62±28.16
	F	1.19	0.40	0.89	0.20	0.70	0.63
	P	**0.2881**	**0.5377**	**0.3575**	**0.6570**	**0.4135**	**0.4375**
sal	Retained	4.02±0.17	17.91±1.38	3.75±0.11	6.39±0.63	1032.30±38.41	364.66±19.60
	Removed	3.97±0.12	17.68±1.01	3.72±0.09	6.34±0.48	1076.59±57.06	385.75±27.35
	F	0.09	0.02	0.06	0.62	0.00	0.62
	P	**0.7724**	**0.8894**	**0.8122**	**0.4424**	**0.9531**	**0.4424**
non-sal	Retained	1.60±0.16	3.42±0.66	2.39±0.12	0.97±0.25	41.48±6.95	11.51±2.60
	Removed	1.41±0.15	2.74±0.50	2.29±0.09	0.73±0.15	47.95±8.70	12.87±2.63
	F	1.27	0.89	0.51	0.75	0.36	0.14
	P	**0.2746**	**0.3578**	**0.4858**	**0.3997**	**0.5569**	**0.7122**
top trees	Retained	7.05±0.20	40.34±2.34	6.00±0.18	16.62±1.31	403.37±23.44	166.17±13.11
	Removed	7.37±0.24	44.37±3.05	6.04±0.20	18.52±1.75	443.73±30.53	185.18±17.48
	F	1.53	1.65	0.04	1.09	1.63	1.09
	P	**0.2307**	**0.2161**	**0.8532**	**0.3088**	**0.2171**	**0.3088**
fat trees	Retained	7.35±0.19	43.29±2.31	5.77±0.17	17.24±1.32	432.92±23.11	172.38±13.21
	Removed	7.68±0.24	47.69±3.13	5.82±0.22	19.20±1.78	476.88±31.33	192.01±17.78
	F	1.84	2.07	0.03	1.18	2.00	1.18
	P	**0.1904**	**0.1688**	**0.8585**	**0.2916**	**0.1733**	**0.2916**

Table 5.3: Initial status of Rapti forest at different lopping intensities

	Lopping %	Mean tree				Mean plot	
		dbh cm	basal area cm^2	height m	tree volume dm^3	basal area cm^2	Volume dm^3
all spp	0	1.53±0.07	3.49±0.34	2.36±0.05	0.97±0.12	475.77±66.73b	132.60±21.60b
	40	1.73±0.13	4.47±0.49	2.52±0.11	1.34±0.18	590.52±60.83ab	175.48±20.33ab
	60	1.76±0.09	4.63±0.40	2.54±0.07	1.36±0.14	700.65±58.24a	205.95±20.54ab
	80	1.83±0.07	4.98±0.32	2.63±0.06	1.54±0.11	705.44±51.96a	217.73±17.81a
	F	1.84	2.50	2.09	3.04	3.21	3.45
	P	**0.1742**	**0.0945**	**0.1357**	**0.0543**	**0.0462**	**0.0371**
sal	0	1.81±0.11b	4.43±0.49b	2.54±0.07b	1.26±0.16b	420.80±59.78b	120.55±20.08b
	40	2.10±0.12ab	5.81±0.56ab	2.77±0.11ab	1.76±0.20ab	534.61±49.82ab	162.23±18.31ab
	60	2.17±0.11ab	6.23±0.49ab	2.81±0.10ab	1.90±0.19ab	617.92±48.29ab	188.37±18.74ab
	80	2.33±0.13a	6.92±0.61a	2.99±0.12a	2.21±0.22a	640.74±50.33a	203.67±16.63a
	F	3.36	4.12	3.19	4.13	3.62	3.83
	P	**0.0404**	**0.0229**	**0.0472**	**0.0205**	**0.0320**	**0.0266**
non-sal	0	0.85±0.09	1.22±0.24	1.90±0.05	0.26±0.05	54.97±16.53	12.05±3.54
	40	0.87±0.13	1.26±0.41	1.91±0.09	0.29±0.11	55.91±25.94	13.25±6.82
	60	1.02±0.12	1.70±0.44	2.03±0.08	0.36±0.09	82.74±18.46	17.58±3.97
	80	0.90±0.09	1.37±0.31	1.94±0.06	0.28±0.06	64.70±18.34	14.06±4.68
	F	0.69	0.45	0.65	0.26	0.38	0.21
	p	**0.5693**	**0.7176**	**0.5930**	**0.8522**	**0.7658**	**0.8864**
top trees	0	4.54±0.22b	17.14±1.62b	4.30±0.18b	5.59±0.70b	171.44±16.16b	55.92±7.00b
	40	5.18±0.04ab	21.74±0.24ab	4.70±0.16ab	7.46±0.25ab	217.43±2.43ab	74.59±2.50ab
	60	5.55±0.21a	25.34±1.94a	4.80±0.19ab	8.84±0.94a	253.35±19.40a	88.42±9.40a
	80	5.47±0.16a	24.75±1.83a	5.09±0.09a	9.17±0.82a	247.47±18.27a	91.73±8.25a
	F	7.33	5.92	4.06	5.09	5.90	5.09
	P	**0.0018**	**0.0059**	**0.0219**	**0.0094**	**0.0051**	**0.0094**
fat trees	0	4.91±0.23b	19.45±1.81b	4.02±0.15b	5.98±0.73b	194.50±18.08b	59.85±7.28b
	40	5.53±0.09ab	24.42±0.76ab	4.50±0.15ab	8.00±0.33ab	244.16±7.57ab	79.97±3.28ab
	60	5.84±0.19a	27.55±1.79a	4.59±0.21ab	9.22±0.90a	275.49±17.89a	92.25±9.05a
	80	5.80±0.18a	27.22±1.97a	4.92±0.09a	9.75±0.87a	272.19±19.71a	97.50±8.70a
	F	5.88	5.52	5.35	5.04	5.20	5.04
	P	**0.0051**	**0.0078**	**0.0076**	**0.0097**	**0.0086**	**0.0097**

Table 5.4: Initial status of Rapti at different litter treatments

	Litter	Mean tree				Plot mean	
		dbh cm	basal area cm^2	height m	stem volume dm^3	basal area cm^2	stem volume dm^3
all spp	Retained	1.75±0.08	4.60±0.33	2.52±0.06	1.37±0.12	636.37±46.32	189.16±16.49
	Removed	1.67±0.06	4.19±0.28	2.50±0.06	1.23±0.10	599.82±51.41	176.72±16.90
	F	0.62	0.98	0.13	1.03	0.36	0.37
	P	**0.4419**	**0.3351**	**0.7219**	**0.3229**	**0.5539**	**0.5501**
sal	Retained	2.17±0.09	6.16±0.43	2.80±0.07	1.88±0.16	579.02±44.92	176.94±16.34
	Removed	2.04±0.10	5.53±0.46	2.76±0.09	1.68±0.17	578.01±41.20	160.47±14.55
	F	1.25	1.48	0.12	1.03	0.95	0.78
	P	**0.2776**	**0.2401**	**0.7317**	**0.3228**	**0.3417**	**0.3867**
non-sal	Retained	0.88±0.08	1.29±0.25	1.93±0.03	0.27±0.05	57.34±12.45	12.23±2.63
	Removed	0.94±0.07	1.49±0.24	1.96±0.06	0.33±0.06	71.81±15.07	16.25±3.89
	F	0.53	0.37	0.13	0.47	0.48	0.61
	P	0.4753	0.5514	0.7252	0.5038	0.4956	0.4466
top trees	Retained	5.29±0.16	23.20±1.43	4.78±0.13	8.81±0.66	232.00±14.34	81.81±6.61
	Removed	5.08±0.17	21.29±1.38	4.66±0.14	7.35±0.61	212.86±13.82	73.52±6.12
	F	1.42	1.55	0.50	1.32	1.54	1.32
	P	**0.2487**	**0.2305**	**0.4901**	**0.2648**	**0.2297**	**0.2648**
fat trees	Retained	5.62±0.15	25.58±1.46	4.54±0.14	8.60±0.68	255.78±14.61	86.01±6.78
	Removed	5.42±0.17	23.74±1.45	4.47±0.14	7.88±0.63	237.39±14.51	78.78±6.33
	F	1.37	1.33	0.22	0.94	1.25	0.94
	P	**0.2567**	**0.2648**	**0.6468**	**0.3437**	**0.2767**	**0.3437**

5.2 Randomness test

Initial plots (no lopping plots of 1997) and random plots (plots established in 1998) were compared for different variables based on 1998 measurements (Tables 5.5 and 5.6) for both forests. Analyses showed no significant difference at the 5% level for any variable in any stratum - all trees, sal trees, and non-sal trees.

Table 5.5: Comparison of initial and random plots in Basanta

		Mean tree				Mean plot	
Strata	Group	dbh cm	basal area cm^2	height m	stem volume dm^3	basal area cm^2	stem volume dm^3
All trees	Initial	3.80±0.25	15.86±0.94	3.66±0.21	5.59±0.37	1168.46± 60.12	410.92±17.16
	Random	3.70±0.22	22.79±5.31	3.69±0.13	11.15±4.02	1683.65±260.98	797.39±208.98
	F	0.09	0.79	0.02	0.89	1.80	1.59
	P	**0.7754**	**0.4036**	**0.8891**	**0.3763**	**0.2217**	**0.2472**
Sal	Initial	4.26±0.016	18.54±0.45	3.94±0.15	6.57±0.19	1128.98±56.03	400.45±14.67
	Random	4.55±0.27	28.17±5.68	4.22±0.21	13.67±4.40	1543.73 ±256.51	738.32±209.03
	F	0.50	1.35	0.77	1.21	1.21	1.22
	P	**0.5004**	**0.2838**	**0.4094**	**0.3069**	**0.3080**	**0.3062**
Non-sal	Initial	1.73±0.56	3.65±2.06	2.40±0.37	0.99±0.63	39.47±15.67	10.47±5.07
	Random	1.39±0.17	4.83±2.22	2.39±0.14	1.90±1.08	139.92±102.84	59.08±48.30
	F	0.57	0.11	0.00	0.31	0.44	0.47
	P	**0.4737**	**0.7471**	**0.9857**	**0.5958**	**0.5269**	**0.5144**

Table 5.6: Comparison of initial and random plots Rapti

Strata	Group	Mean tree				Mean plot	
		dbh cm	basal area cm^2	height m	stem volume dm^3	basal area cm^2	stem volume dm^3
All trees	Initial	2.03±0.14	5.64±0.67	2.72±0.11	1.74±0.23	752.45± 82.50	231.55±26.18
	Random	1.82±0.09	5.22±0.52	2.64±0.09	1.66±0.21	704.21±52.15	223.54±23.22
	F	1.66	0.23	0.31	0.06	0.27	0.04
	P	**0.2384**	**0.6466**	**0.5932**	**0.8167**	**0.6219**	**0.8393**
Sal	Initial	2.42±0.21	7.20±1.01	2.98±0.13	2.28±0.35	646.70±74.52	204.49±26.15
	Random	2.37±0.20	7.19±0.96	2.99±0.17	2.31±0.36	624.71±54.52	199.75±22.44
	F	0.03	0.00	0.00	0.00	0.06	0.02
	P	**0.8769**	**0.9928**	**0.9872**	**0.9695**	**0.8209**	**0.9017**
Non-sal	Initial	1.19±0.05	2.18±0.32	2.18±0.04	0.55±0.09	105.75±37.31	27.06±10.29
	Random	0.81±0.12	1.56±0.66	2.00±0.06	0.46±0.25	79.50±34.55	23.79±13.16
	F	4.21	0.40	4.27	0.06	0.22	0.03
	P	**0.0794**	**0.5489**	**0.0777**	**0.8201**	**0.6545**	**0.8772**

5.3 Treatment effects on growth

In Basanta-hariyali community forest, dbh and height of 1842 trees on 24 plots were measured in 1997; 92 of these trees were recorded as dead in 1998. Among living trees, 42, 41 and 106 were found partially damaged due to breakage, cutting and dieback (top-dying), respectively. Breakage, cutting and top-dying resulted in 31 trees lost from the dbh category of trees (with height greater than 1.37 m) whereas 158 trees were recorded shorter than initial height but still remained in dbh category (i.e. taller than 1.37 m). During the 1998 measurement, 228 ingrowth trees were recorded.

In Rapti community forest, 3387 trees were measured on 24 plots in 1997, and 407 of these were recorded as dead in 1998. Among living trees, 197, 209 and 230 were found damaged due to breakage, cutting and top-dying, respectively. Breakage, cutting and top-dying resulted in the loss of 293 trees from dbh category, whereas 343 trees were recorded shorter than initial height but still taller than 1.37 m. Four-hundred and fifty-four trees were recorded as ingrowth in 1998.

In Basanta-hariyali, 335 trees were recorded in the root-collar diameter category (trees between 1 m and 1.37 m high) in 1997, and 60 of these were found dead in 1998. Among survivors, 84 were recorded as ingrowth to the dbh class, and 56 trees were affected by breakage, cutting or top-dying. Twenty-one of the affected trees were recorded lost from this category, and 35 trees were recorded shorter than initial height but remained in the root-collar diameter class (i.e. height between 1-1.37 m). In 1998, additional observations in this category were from ingrowth (263 trees) and loss from the dbh class (28 trees).

In Rapti, 1086 trees were recorded in this category in 1997, and 262 of these were found dead in 1998. Among survivors, 194 were recorded as ingrowth to dbh class, and 302 trees were adversely affected by breakage, cutting or top-dying. One-hundred and seventy trees of these adversely affected were recorded as lost to the lower height category, and the rest (132 trees) were recorded shorter than initial height but remained in the root-collar diameter class (i.e. height between 1-1.37 m). Additional observations in this category were from ingrowth (388 trees) and loss from the dbh class (226 trees).

Table 5.7 gives the summary of the records measured during fieldwork.

Table 5.7: Number of records from two measurements

Category	Year	# Trees measured		
		Basanta	Rapti	Total
Dbh class	1997	1842	3387	5229
	1998	1947	3141	5088
Root-collar diameter class	1997	335	1086	1421
	1998	461	1074	1535

Out of 1719 trees in Basanta and 2687 trees in Rapti measured during both years, 50 (2.91%) and 101 (3.76%) tree measurements gave negative dbh growth in Basanta and Rapti, respectively. The detailed breakdown of these diameter losses is presented in Table 5.8, and the negative growth ranged up to 0.1 cm dbh. However, 71% (42% in Basanta, and 85% in Rapti) of these records were less than 0.1 cm. Sixty per cent (30% in Basanta and 75% in Rapti) of the negative dbh measurements were in trees of dbh less than 1 cm.

Table 5.8: Data errors in dbh growth

FUG	Range of negative dbh growth (cm)	Number of trees with negative dbh growth in each dbh class (cm)							
		< 1	1-2	2-3	3-4	4-5	5-6	6-7	Total
BH	< 0.05	1	0	0	0	0	0	0	1
	0.05-0.10	9	1	3	1	2	2	2	20
	0.10	5	0	2	4	7	7	4	29
	Total	**15**	**1**	**5**	**5**	**9**	**9**	**6**	**50**
RP	< 0.05	32	3	0	0	0	0	0	35
	0.05-0.10	35	14	2	0	0	0	0	51
	0.10	9	1	2	2	1	0	0	15
	Total	**76**	**18**	**4**	**2**	**1**	**0**	**0**	**101**

Similarly, measurements of 152 (8.84%) and 345 (12.84%) trees indicated reduced height in Basanta and Rapti, respectively. The detailed breakdown of tree height reduction is presented in Table 5.9. Of these records 82% in Basanta and 84% in Rapti were less than 0.5 m loss. The causes of height reduction have been noted as breaking, cutting and top-dying (Table 5.10). Breaking and top-dying are natural phenomena, whereas 3.11% (1.69 % in Basanta and 4.02% in Rapti) of the trees has been recorded as tip-cut by local people. Also it was recorded that most of such cuts were made during October-November, i.e. just before the second measurement, suggesting that this cutting would have had little effect on dbh growth. The tips were cut possibly for collecting fodder.

Table 5.9: Detail of height-reduced trees

FUG	Range (m)	Number of trees with reduced height in each height class (m)						
		<2	2-3	3-4	4-5	5-6	>6	Total
BH	< 0.1	31	19	6	3	3		62
	0.1-0.5	21	22	7	5	5	2	62
	0.5-1.0	1	17	4		1		23
	1.0-1.5	0	0	2	1	0	1	4
	1.5-2.0	0	0	1	0	0	0	1
	Total	**53**	**58**	**20**	**9**	**9**	**3**	**152**
RP	< 0.1	74	53	7	0	0	0	134
	0.1-0.5	70	71	10	4	0	0	155
	0.5-1.0	3	30	11	1	0	0	45
	1.0-1.5	0	1	8	1	0	0	10
	1.5-2.0	0	0	0	0	1	0	1
	Total	**147**	**155**	**36**	**6**	**1**	**0**	**345**

Table 5.10: Causes of height reduction

FUG	Range (m)	Broken	Cut	Top dying	Not known	Total
BH	< 0.1	7	2	51	2	62
	0.1-0.5	5	15	42	0	62
	0.5-1.0	11	9	3	0	23
	1.0-1.5	2	2	0	0	4
	1.5-2.0	0	1	0	0	1
	Total	**25**	**29**	**96**	**2**	**152**
RP	< 0.1	12	26	93	3	134
	0.1-0.5	40	53	62	0	155
	0.5-1.0	16	22	7	0	45
	1.0-1.5	3	7	0	0	10
	1.5-2.0	1	0	0	0	1
	Total	**72**	**108**	**162**	**3**	**345**

Depending upon the nature of the experimental forests, the cases presented in Tables 5.8 through 5.10 are not unusual, and such errors cannot be totally avoided. Analyses were done with edited (i.e. setting the negative growth to zero) and unedited (recorded) data, and the results of analyses were unchanged. The analyses reported were based on the recorded values.

Tests, such as i) test of homogeneity of variance ii) Bartlett's test of homogeneity and iii) site and treatment interactions from combined ANOVA, revealed that the variances of measurements from the two sites were not heterogeneous. The two forests showed significant differences when compared (ANOVA) in their initial status and increments for different variables (Tables 5.11 and 5.12). Thus, separate site-specific analyses were performed.

Table 5.11: Comparison of initial status in two sites

	FUG	Mean tree				Mean plot	
		dbh cm	Basal area cm^2	height m	Volume dm^3	basal area cm^2	stem volume dm^3
All	Basanta	3.46±0.07	14.58±0.55	3.43±0.05	5.15±0.25	1099.16±35.40	387.40±16.92
	Rapti	1.71±0.05	4.39±0.22	2.51±0.04	1.30±0.08	618.09±34.05	182.94±11.62
	F	398.62	295.27	221.38	209.05	95.93	99.17
	P	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Sal	Basanta	4.00±0.10	17.80±0.84	3.74±0.07	6.36±0.39	1054.44±33.95	375.21±16.60
	Rapti	2.10±0.07	5.85±0.31	2.78±0.06	1.78±0.11	553.52±30.28	168.71±10.84
	F	243.16	178.73	116.69	127.53	121.25	108.51
	P	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Non-sal	Basanta	1.50±0.11	3.08±0.41	2.33±0.08	0.85±0.14	44.72±5.49	12.19±1.81
	Rapti	0.91±0.05	1.39±0.17	1.95±0.03	0.30±0.04	64.58±9.68	14.24±2.33
	F	23.34	14.50	22.12	13.79	3.19	0.48
	P	**0.0001**	**0.0004**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Top10	Basanta	7.21±0.16	42.36±1.93	6.02±0.13	17.57±1.09	423.55±19.29	175.68±10.89
	Rapti	5.19±0.12	22.24±0.99	4.72±0.10	7.77±0.45	222.43±9.94	77.67±4.49
	F	108.80	85.91	63.70	69.47	85.91	69.47
	P	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Fat 10	Basanta	7.52±0.15	45.49±1.96	5.79±0.14	18.22±1.10	454.90±19.58	182.20±11.02
	Rapti	5.52±0.11	24.66±1.03	4.50±0.10	8.24±0.46	246.59±10.23	82.39±4.60
	F	108.90	88.80	57.38	69.83	88.80	69.83
	P	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**

Table 5.12: Comparison of increments in two sites

	FUG	Mean tree				Mean plot	
		dbh cm	basal area cm^2	height m	volume dm^3	basal area cm^2	volume dm^3
All survivor	Basanta	0.39±0.01	2.49±0.09	0.36±0.01	1.33±0.06	176.82±6.94	93.90±4.22
	Rapti	0.46±0.01	2.35±0.09	0.33±0.01	0.93±0.04	260.01±10.21	102.40±4.38
	F	14.52	1.07	3.19	35.31	57.06	2.44
	P	**0.0005**	**0.3057**	**0.0822**	**0.0001**	**0.0001**	**0.1271**
Net	Basanta					166.49	91.20
	Rapti					237.51	98.29
	F					25.60	1.54
	P					**0.0001**	**0.2220**
sal survivors	Basanta	0.38±0.01	2.79±0.12	0.38±0.02	1.57±0.08	156.17±6.80	87.15±4.04
	Rapti	0.53±0.02	2.99±0.12	0.37±0.02	1.20±0.06	239.65±9.60	95.97±4.28
	F	42.92	1.41	0.37	17.11	72.00	3.12
	P	**0.0001**	**0.2416**	**0.5469**	**0.0002**	**0.0001**	**0.0854**
Sal net	Basanta					144.93	84.262
	Rapti					229.67	94.17
	F					52.40	3.80
	P					**0.0001**	**0.0588**
Non-sal survivors	Basanta	0.40±0.03	1.34±0.17	0.31±0.02	0.45±0.06	20.65±3.06	6.75±1.03
	Rapti	0.26±0.02	0.65±0.06	0.23±0.04	0.20±0.02	20.36±2.71	6.42±1.05
	F	13.47	13.84	2.98	14.89	0.01	0.05
	P	**0.0006**	**0.0005**	**0.0913**	**0.0004**	**0.9430**	**0.8237**
top 10	Basanta	0.41±0.02	5.01±0.38	0.57±0.03	3.52±0.27	50.08±3.77	35.18±2.68
	Rapti	0.85±0.03	7.65±0.28	0.65±0.02	3.67±0.14	76.49±2.79	36.67±1.36
	F	160.18	31.73	4.46	0.28	41.63	0.28
	P	**0.0001**	**0.0001**	**0.0415**	**0.5974**	**0.0001**	**0.5974**
Fat 10	Basanta	0.44±0.03	5.54±0.41	0.67±0.03	4.00±0.29	55.36±4.10	40.00±2.86
	Rapti	0.84±0.03	7.98±0.31	0.76±0.03	3.97±0.15	79.76±3.14	39.66±1.54
	F	144.20	22.35	3.51	0.01	33.25	0.01
	P	**0.0001**	**0.0001**	**0.0687**	**0.9046**	**0.0001**	**0.9046**

5.3.1 Effects on diameter at breast height increment

Lopping effects

The effects of lopping intensity on mean tree dbh increments were analyzed for survivors (Tables 5.13) and dominant trees (Tables 5.14). Lopping did not produce any significant differences in diameter increment at the 5% significance level in any stratum in Basanta-hariyali forest. In Rapti, lopping showed significant results at the 5% significance level only for dominant trees. Significant results with the Tukey classification at the 5% significance level are presented in Figure 5.1.

Table 5.13: Mean tree dbh increment (cm) by lopping intensities (survivors)

Forest	Lopping	All species	Sal	Non-sal
BH	0	0.40±0.02	0.39±0.04	0.39±0.08
	40	0.34±0.03	0.34±0.03	0.37±0.05
	60	0.39±0.02	0.39±0.03	0.38±0.08
	80	0.42±0.02	0.40±0.03	0.46±0.03
Test statistics	F value	1.71	0.94	0.78
	P value	**0.1988**	**0.4415**	**0.5199**
RP	0	0.43±0.02	0.47±0.02	0.33±0.04
	40	0.50±0.02	0.58±0.03	0.23±0.03
	60	0.46±0.02	0.56±0.02	0.21±0.03
	80	0.45±0.03	0.52±0.04	0.30±0.05
Test statistics	F value	1.20	2.61	2.17
	P value	**0.3380**	**0.0811**	**0.1250**

Table 5.14: Mean tree dbh increment for top trees by lopping intensities

Lopping	Mean dbh increment of 10 fattest trees (cm)		Mean dbh increment of 10 tallest trees (cm)	
	Basanta	Rapti	Basanta	Rapti
0	0.46±0.05	0.83±0.04ab	0.40±0.03	0.91±0.04a
40	0.50±0.05	0.97±0.05a	0.45±0.06	0.95±0.04a
60	0.47±0.07	0.88±0.05a	0.45±0.07	0.88±0.03a
80	0.34±0.03	0.67±0.04b	0.34±0.03	0.67±0.05b
F value	1.89	8.73	1.05	8.15
P value	0.1651	0.0008	0.3948	0.0011

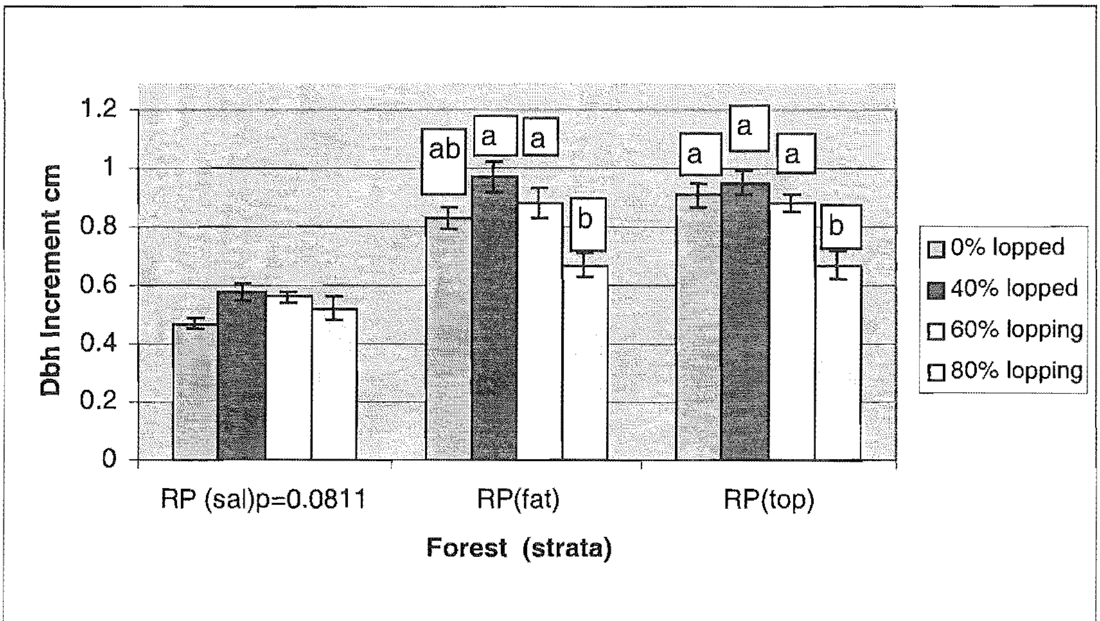

Figure 5.1: Tree dbh increment in different strata of Rapti

Effects of litter removal

Dbh increments by litter treatment are presented for survivors (Table 5.15) and dominant trees (Table 5.16); no significant effects are indicated at the 5% significance level.

Table 5.15: Tree dbh increment (cm) by litter treatments

Site	Litter	All species	Sal	Non-sal
BH	Retained	0.39±0.02	0.39±0.02	0.35±0.03
	Removed	0.39±0.02	0.37±0.02	0.45±0.05
		0.00 **0.9736**	0.49 **0.4920**	4.12 **0.0584**
RP	Retained	0.46±0.02	0.54±0.02	0.26±0.03
	Removed	0.46±0.02	0.53±0.03	0.27±0.03
	F P	0.00 **0.9729**	0.03 **0.8632**	0.02 **0.8796**

Table 5.16: Tree dbh increment (cm) by litter treatments

Litter	Mean dbh increment of 10 fattest trees		Mean dbh increment of 10 tallest trees	
	Basanta	**Rapti**	**Basanta**	**Rapti**
Retained	0.45±0.04	0.82±0.04	0.43±0.04	0.83±0.04
Removed	0.43±0.04	0.85±0.04	0.39±0.03	0.87±0.05
F P	0.18 0.6755	0.34 0.5679	0.58 0.4546	0.72 0.4051

Summary of treatment effects on diameter at breast height increment:

- Only 80% lopping adversely affected the mean dbh increment in two strata (tallest and largest trees in Rapti), where lopping produced significant results at the 5% significance level (Table 5.14). Forty percent lopping produced the greatest increment in these strata, and up to 60 % lopping did not show significant adverse effects on dbh increment (Table 5.14). The effects are consistently in the same trend in both strata (Figure 5.1). Although results are not significant at the 5% significance level in sal trees of Rapti, the trend is not different (except 80% is not less than no lopping) from the other two significant results (Figure 5.1).

- Litter removal did not produce any significant effects on dbh increment in any strata of either forest.

- ANOVA showed no interaction effects between lopping and litter on dbh increment in either forest.

5.3.2 Effects on mean tree basal area increment

Lopping effects

Tree-level basal area increments ranged from 0.48 cm^2 $tree^{-1}$ ($0.48*10^{-4}$ m^2) for the non-sal group to 9.32 cm^2 $tree^{-1}$ ($9.32*10^{-4}$ m^2) for the dominant tree group (largest trees in Rapti). Lopping produced no significant effect on the tree basal area increment in any strata at Basanta-hariyali, but effects were significant in all strata except non-sal in Rapti forest (Tables 5.17 and 5.18). Mean basal area increments of all strata with significant effects of lopping are presented in Figure 5.2.

Table 5.17: Mean tree basal area increment in cm^2 by lopping intensities

Forest	Lopping	All species	Sal	Non-sal
Basanta	0	2.52±0.17	2.71±0.20	1.38±0.56
	40	2.53±0.22	2.87±0.22	1.29±0.20
	60	2.51±0.16	2.95±0.26	1.07±0.38
	80	2.38±0.21	2.61±0.28	1.61±0.17
		0.13 0.9425	0.40 0.7556	0.59 0.6282
Rapti	0	1.94±0.10b	2.31±0.13b	0.84±0.10
	40	2.70±0.17a	3.34±0.17a	0.61±0.16
	60	2.48±0.13ab	3.29±0.12a	0.48±0.09
	80	2.30±0.16ab	3.01±0.27ab	0.66±0.15
F value P value		4.87 0.0112	6.45 0.0034	1.37 0.2824

Table 5.18: Mean tree basal area increment for top trees by lopping intensities

Lopping	Mean basal area increment of 10 fattest trees (cm^2)		Mean basal area increment of 10 tallest trees (cm^2)	
	Basanta	**Rapti**	**Basanta**	**Rapti**
0	5.33±0.65	7.23±0.37bc	4.44±0.40	7.41±0.28ab
40	6.74±0.83	9.32±0.50a	5.87±0.87	8.58±0.43a
60	6.18±0.89	8.75±0.45ab	5.88±0.90	8.35±0.34a
80	3.89±0.51	6.61±0.51c	3.85±0.49	6.25±0.61b
F	2.69	7.21	2.06	5.64
P	0.0757	0.0020	0.1392	0.0062

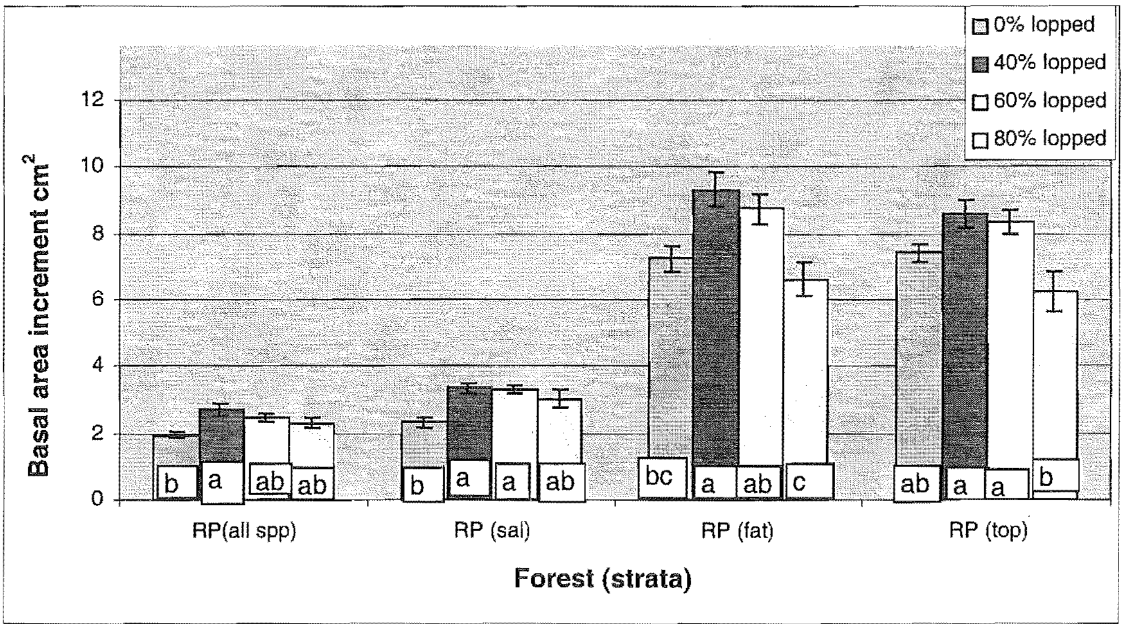

Figure 5.2: Tree basal area increment in different strata of Rapti

Effects of litter treatment

Effects of litter removal on mean-tree basal area increment are presented in Tables 5.19 and 5.20, and indicated no significant differences in any strata in either forest.

Table 5.19: Mean tree basal area increment (cm^2) by litter treatment

Forest	Litter	All species	Sal	Non-sal
BH	Retained	2.55±0.12	2.88±0.14	1.16±0.18
	Removed	2.42±0.13	2.69±0.19	1.52±0.30
		0.50 0.4900	0.63 0.4368	1.54 0.2308
RP	Retained	2.38±0.12	3.03±0.17	0.64±0.10
	Removed	2.33±0.13	2.94±0.18	0.66±0.09
F P		0.14 0.7080	0.23 0.6340	0.02 0.9032

Table 5.20: Mean tree basal area increment for top trees by litter treatments

Litter	Mean basal area increment of 10 fattest trees (cm^2)		Mean basal area increment of 10 tallest trees (cm^2)	
	Basanta	Rapti	Basanta	Rapti
Retained	5.57±0.54	8.01±0.39	5.15±0.54	7.68±0.32
Removed	5.50±0.64	7.94±0.51	4.86±0.55	7.62±0.47
F P	0.01 0.9226	0.02 0.8837	0.16 0.6910	0.02 0.8805

Summary of the effects of treatments on basal area increment:

- Lopping produced significant effects at the 5% significance level on basal area increment in all strata except the non-sal stratum of Rapti, but none in Basanta-hariyali (Table 5.17).
- In Rapti, 40% lopping produced highest basal area increment in all strata (Figure 5.2). In case of all-species and sal strata, lopping (40-80%) increased the growth, and the increment at 40% lopping was significantly greater than at 0% lopping. But in the case of dominant (largest and tallest) trees, 80% lopping produced the least increment, and this was significantly lower than increment under 40 and 60% lopping.
- Litter removal did not have significant effects on the mean basal area increment in any strata of either forest.
- Interactions between lopping and litter treatment were absent in all strata in both forests.

5.3.3 Effects on mean height increment

Lopping effects

Tree height increment ranged from 0.29 to 0.72 m in Basanta-hariyali and 0.14 to 0.80 m in Rapti. No effect at 5% significance level of lopping (Tables 5.21 and 5.22) on mean height increment occurred in Basanta-hariyali. In Rapti, significant effects occurred in all-species and sal strata (Table 5.21, Figure 5.3).

Table 5.21: Mean tree height increments in m by lopping intensities

Forest	Lopping	Mean tree height increment m		
		All species	Sal	Non-sal
BH	0	0.33±0.02	0.33±0.01	0.32±0.04
	40	0.36±0.02	0.38±0.03	0.32±0.09
	60	0.39±0.03	0.42±0.05	0.30±0.22
	80	0.38±0.02	0.41±0.03	0.29±0.03
Test statistics	F	1.21	2.45	0.08
	P	0.3321	0.0970	0.9703
RP	0	0.31±0.03ab	0.33±0.04b	0.25±0.03
	40	0.39±0.03a	0.43±0.05a	0.32±0.05
	60	0.28±0.01b	0.34±0.03b	0.14±0.09
	80	0.33±0.02ab	0.38±0.03ab	0.22±0.10
Test statistics	F	4.58	4.36	2.57
	P	0.0141	0.0188	0.0886

Table 5.22: Mean tree height increments for top trees by lopping intensities

Lopping	Mean height increment for fattest 10 trees m		Mean height increment for tallest 10 trees m	
	Basanta	Rapti	Basanta	Rapti
0	0.61±0.07	0.80±0.07	0.53±0.06	0.64±0.04
40	0.69±0.04	0.77±0.05	0.55±0.04	0.67±0.05
60	0.72±0.10	0.78±0.07	0.62±0.06	0.69±0.05
80	0.66±0.05	0.70±0.06	0.57±0.06	0.60±0.05
F	0.42	0.42	0.18	2.88
P	0.7407	0.7410	0.9060	0.0684

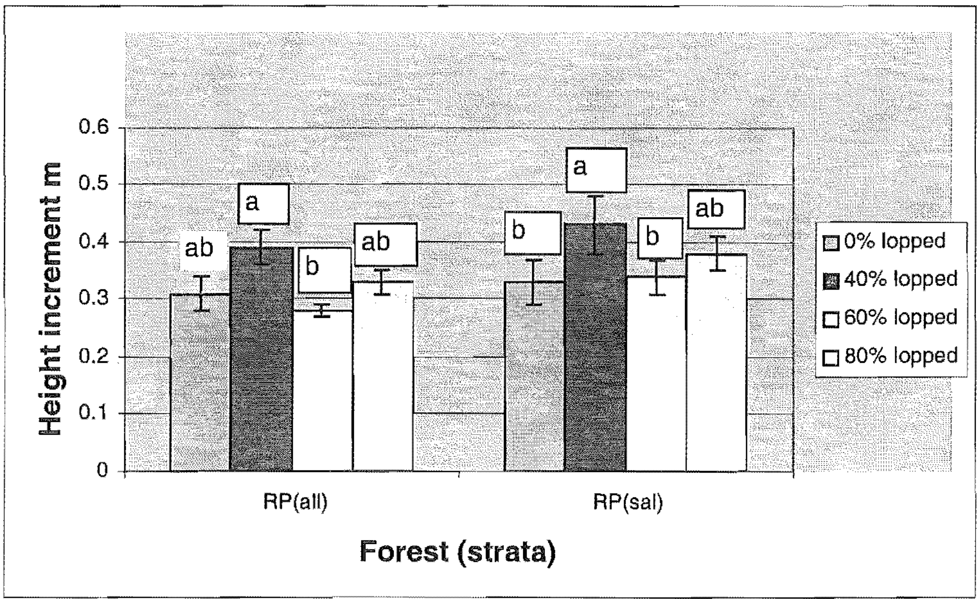

Figure 5.3: Tree height increments in different strata of Rapti

Effects of litter removal

Litter removal did not produce significant differences in tree height increment in any strata of either forest (Tables 5.23 and 5.24). However, in many of the cases, litter removal reduced height increment.

Table 5.23: Mean tree height increments by litter treatments

Forest	Litter	Mean tree height increment m		
		All species	Sal	Non-sal
BH	Retained	0.37±0.02	0.39±0.03	0.30±0.02
	Removed	0.36±0.02	0.38±0.02	0.32±0.04
F		0.19	0.23	0.14
P		0.6643	0.6377	0.7133
RP	Retained	0.34±0.02	0.39±0.03	0.21±0.06
	Removed	0.32±0.02	0.35±0.03	0.25±0.05
F		0.58	2.16	0.74
P		0.4567	0.1603	0.4018

Table 5.24: Mean tree height increments for top trees by litter treatments (site-specific)

Litter	Mean tree height increment of fattest 10 trees (m)		Mean height increment of tallest 10 trees (m)	
	Basanta	Rapti	Basanta	Rapti
Retained	0.65±0.04	0.80±0.05	0.56±0.04	0.67 ±0.03
Removed	0.69±0.05	0.72±0.04	0.57±0.04	0.63±0.04
F	0.30	3.20	0.01	4.34
P	0.5901	0.0906	0.9078	0.0535

Summary of treatment effects on tree height increment:

- Lopping did not produce any significant effects at the 5% significance level on height increment in any strata in Basanta-hariyali. In Rapti, lopping produced significant results at 5% significance level on height increment only in the all-tree and sal strata. Forty percent lopping produced the highest tree height increment in both the strata, but it is only significantly different at 5% significance level from 60% lopping. Other lopping intensities did not differ significantly from each other.
- Litter removal did not produce significant differences in mean tree height increment during the study period.
- Interactions between lopping and litter removal were not significant for tree height increment in either forest.

5.3.4 Effects on mean-tree volume

Lopping effects

Mean-tree volume increment ranged from 0.35 to 4.80 dm^3 ($0.35*10^{-3}$ to $4.80*10^{-3} m^3$) in Basanta-hariyali and 0.11 to 4.46 dm^3 ($0.11*10^{-3}$ to $4.46*10^{-3} m^3$) in Rapti. Lopping did not show any significant differences in mean-tree volume increment at the 5% significance level in any strata of Basanta-hariyali, but produced significant differences in all strata of Rapti (Tables 5.25 and 5.26). Groupings based on Tukey's test are presented in respective tables and also in Figure 5.4.

Table 5.25: Mean tree volume increments (dm^3) by lopping intensities

Forest		Mean tree volume increment m		
	Lopping	All species	Sal	Non-sal
BH	0	1.23±0.10	1.37±0.09	0.49±0.22
	40	1.42±0.11	1.70±0.13	0.45±0.08
	60	1.45±0.11	1.82±0.21	0.35±0.08
	80	1.18±0.11	1.39±0.15	0.51±0.07
Test statistics	F	0.08	0.27	0.55
	P	0.9677	0.8440	0.6550
	Covariate F	5.79	8.77	n. s.[4]
	P	0.0285	0.0092	
RP	0	0.82±0.06b	1.03±0.08b	0.27±0.03a
	40	1.06±0.05a	1.34±0.07a	0.21±0.03a
	60	0.96±0.05ab	1.28±0.07a	0.11±0.03b
	80	0.89±0.06b	1.15±0.08ab	0.20±0.03ab
Test statistics	F	3.28	3.35	4.45
	P	0.0449	0.0422	0.0165
	Covariate F	10.96	12.02	28.67
	P	p=0.0039	0.0028	0.0001

[4] Not significant at 5% level of significance.

Table 5.26: Mean tree volume increments (dm^3) by lopping intensities for dominant trees

Lopping	Mean tree volume increment in m fattest 10 trees		Mean tree volume increment in m tallest 10 trees	
	Basanta	Rapti	Basanta	Rapti
0	3.41±0.32	3.42±0.26b	2.84±0.28	3.76±0.22 a
40	4.75±0.55	4.46±0.22a	3.98±0.55	4.09±0.18 a
60	4.80±0.70	4.36±0.19ab	4.42±0.67	3.82±0.19 a
80	3.04±0.35	3.63±0.35ab	2.82±0.32	3.00±0.20 b
F	0.59	3.96	0.16	6.13
P	0.6283	0.0239	0.9194	0.0047
Covariate F	n.s.	n.s.	n.s.	15.83
P				0.0009

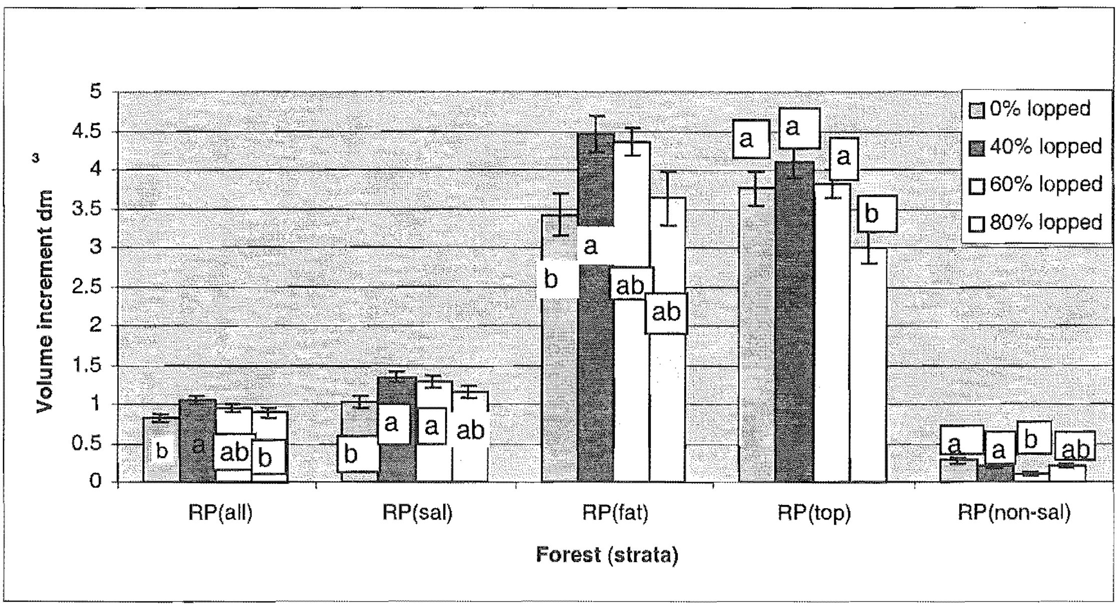

Figure 5.4: Tree volume increments for different strata of Rapti

Effects of litter removal

Litter removal did not show any significant effects on the mean tree volume increment in any strata of either forest. However, except in non-sal, tallest-tree and fattest-tree strata of Basanta-hariyali, litter removal lowered mean tree volume increment (Tables 5.27 and 5.28).

Table 5.27: Tree volume increments by litter treatments

Forest		Mean tree volume increment (dm^3)		
	Litter	All species	Sal	Non-sal
BH	Retained	1.36±0.07	1.62±0.11	0.40±0.06
	Removed	1.28±0.09	1.52±0.12	0.50±0.11
Test statistics		0.29	0.55	0.91
		0.5998	0.4689	0.3536
RP	Retained	0.96±0.06	1.24±0.08	0.20±0.04
	Removed	0.90±0.05	1.16±0.08	0.20±0.03
Test statistics		0.13	0.07	0.48
		0.7232	0.7881	0.4984

Table 5.28: Tree volume increments for dominant trees by litter treatments

Litter	Mean tree volume increment fattest 10 trees (dm^3)		Mean tree volume increment tallest 10 trees (dm^3)	
	Basanta	Rapti	Basanta	Rapti
Retained	3.91±0.38	4.11±0.16	3.51±0.37	3.79 ±0.15
Removed	4.09±0.45	3.82±0.26	3.52±0.41	3.54±0.02
F	0.21	1.25	0.93	1.14
P	0.6547	0.2766	0.3485	0.2982

Summary of treatment effects on tree volume increment:

- Lopping showed no significant effects at the 5% significant level in any strata on tree volume increment in Basanta-hariyali, but the effects were significant in all strata of Rapti. Forty percent lopping showed the highest tree volume increment except in the non-sal stratum. Also 60% lopping did not adversely affect the increment as compared to 0 or 80% lopping in all strata except the non-sal stratum. In all-species, sal, and largest (diameter) tree strata, 40% lopping produced significantly higher increment than no-lopping.

- In the case of the non-sal stratum, lopping reduced the mean tree volume increment, but the trend was inconclusive.

- Litter removal lowered the mean tree volume increment but not significantly at the 5% significance level. No interactions between lopping and litter removal were significant at the 5% significance level.

5.4 Treatment effects at the plot level

Plot size was 50 m^2 (0.005 ha), and the plot-level increments were assessed by the mean plot value (see plot-level analysis in 3.8). Increments of plot basal area and stem volume were assessed for different strata.

5.4.1 Effects on plot basal area

Treatment effects on mean plot basal area are presented in Tables 5.29 through 5.34. Mean plot basal area increment ranged from 158.77 to 173.16 cm^2 (3.175 to 3.463 m^2 ha^{-1}) at Basanta, and 213.71 to 275.74 cm^2 (4.274 to 5.515 m^2 ha^{-1}) at Rapti.

Lopping effects

Lopping effects were not significant on plot basal area increments in any stratum of Basanta-hariyali (Tables 5.29 through 5.31). In Rapti, too, only some strata - survivors (all species), sal (net) and sal (survivors) - produced significant response to lopping, but other strata did not show any effect (Tables 5.29 through 5.31). None of the cases showed any significant differences in ingrowth or mortality. Groupings of those strata with significant effects and levels of significance are presented in Figure 5.5.

Table 5.29: Plot basal area increments (all species) in cm^2 by lopping intensities

Forest	Lopping %	Plot-net	Survivor	Ingrowth	Mortality
BH	0	173.16±10.58	174.63 ± 11.12	4.35± 1.28	5.82± 3.13
	40	170.07±10.11	178.06± 7.87	4.23± 1.79	12.21± 6.71
	60	158.77± 21.82	180.46± 24.41	2.15± 0.47	23.90± 16.83
	80	164.03 ± 8.64	174.14±10.02	7.86± 3.52	17.97± 9.62
Test statistics	F	0.21	0.04	1.24	0.64
	P	0.8891	0.9896	0.3222	0.5988
RP	0	213.71± 20.26	236.95±13.53b	7.45± 4.17	12.41± 2.42
	40	275.74± 20.77	289.24±11.94a	4.24± 1.37	14.20± 3.40
	60	254.08± 22.29	279.52±12.45a	3.04± 0.72	39.07± 16.13
	80	206.52± 30.98	234.33±12.52b	3.67± 1.27	42.70± 15.93
Test statistics	F	2.88	5.66	0.69	1.67
	P	0.0662	0.0077	0.5681	0.2184
	Covariate F	n.s.	6.51	n.s.	n.s.
	P		0.0124		

Table 5.30: Plot basal area increments (cm^2) for sal by lopping intensities

Forest	Lopping %	Sal stand	Sal survivor	Ingrowth	Mortality
BH	0	153.76± 11.04	156.73±11.34	2.30±0.89	5.27±2.69
	40	151.64± 9.49	160.48±7.80	2.65±1.39	11.49±6.35
	60	140.18± 22.02	162.09±23.09	1.30±0.28	23.21±16.78
	80	134.16± 6.86	145.38±9.69	6.45±3.64	17.67±9.67
Test statistics	F	0.48	0.27	1.23	0.64
	P	0.7018	0.8476	0.3275	0.5968
RP	0	192.05± 17.05 b	209.51±11.58b	4.74±3.89	5.68±2.19
	40	261.43± 16.75 a	269.69±10.02a	1.81±0.96	7.71±1.97
	60	258.41± 11.53 a	264.72±10.38a	1.27±0.60	15.59±5.71
	80	206.80± 26.35 ab	214.68±10.70b	1.11±0.37	19.84±14.81
Test statistics	F	5.82	9.97	0.68	0.73
	P	0.0069	0.0006	0.5776	0.8434
	Covariate F	n.s.	7.65	n.s.	n.s.
	P		0.0160		

Table 5.31: Mean plot basal area increments (cm^2)of non-sal by lopping intensities

Forest	Lopping %	Net	Survivor	Ingrowth	Mortality
BH	0	19.39± 9.55	17.90± 9.24	2.05±0.53	3.30± (one plot only)
	40	18.44± 2.24	17.59± 1.65	1.57±0.73	2.17±0.82
	60	18.54± 5.36	18.38± 5.58	1.02±0.34	1.03±0.43
	80	29.87± 6.04	28.76±5.96	1.41±0.41	0.61±0.34
Test statistics	F	0.79	0.86	0.57	4.87
	P	0.5156	0.4783	0.6442	0.0605
RP	0	21.66± 6.73	25.68± 5.59	2.71±0.40	6.73±2.65
	40	14.31± 5.77	18.36± 7.59	2.43±0.67	6.49±2.33
	60	-4.33± 13.56	17.39± 4.38	1.76±0.46	23.48±11.71
	80	-0.28± 10.14	20.01± 4.38	2.57±1.27	22.86±11.28
Test statistics	F	1.68	2.61	0.27	1.32
	P	0.2091	0.0833	0.8434	0.2974

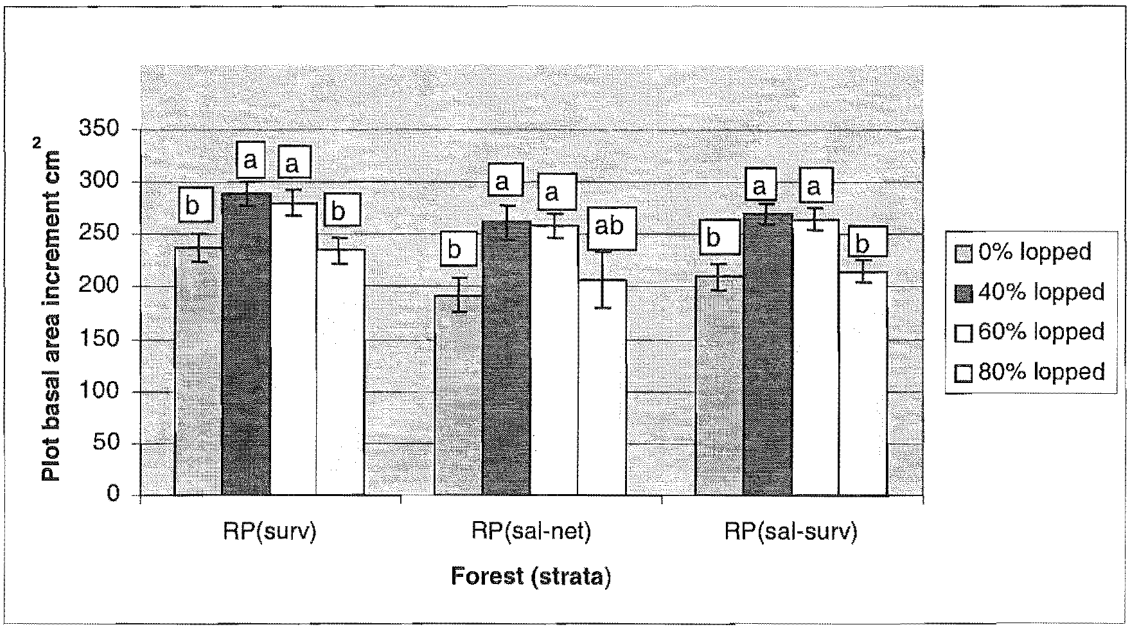

Figure 5.5: Plot basal area increments for different strata of Rapti

Effects of litter removal on plot basal area increment

Basal area increments by ground-litter treatment are given in Tables 5.32 through 5.34 for different strata. In none of the strata in either forest did litter removal produce significant effects on plot basal area increment. Also the effects of litter removal on ingrowth and mortality showed no significant differences.

Table 5.32: Mean plot basal area increments (cm^2) of all species by litter treatments

Forest	Litter	Plot-net	Survivor	Ingrowth	Mortality
BH	Retained	170.58± 9.43	176.46± 9.85	5.27± 1.92	11.14± 5.32
	Removed	162.41± 9.35	177.19± 10.23	4.03 ± 0.99	18.81± 8.67
Test statistics	F	0.34	0.00	0.34	0.63
	P	0.5681	0.9624	0.5680	0.4391
RP	Retained	242.54± 17.07	263.23± 11.38	5.35± 2.15	26.04± 8.00 a
	Removed	232.49± 19.35	256.79± 17.44	3.85± 0.83	28.15± 9.57 a
Test statistics	F	0.27	0.02	0.40	0.03
	P	0.6116	0.8854	0.5346	0.8556

Table 5.33: Mean plot basal area increments (cm^2) for sal by litter treatments

Forest	Litter	Sal stand	Sal Survivor	Ingrowth	Mortality
BH	Retained	152.83± 8.61	159.91± 9.28	3.79±1.92	10.87±5.29
	Removed	137.04±9.78	152.43± 10.23	2.56±0.78	17.95±8.60
Test statistics	F	1.37	0.26	0.36	0.54
	P	0.2570	0.6133	0.5536	0.4727
RP	Retained	230.70± 15.66	243.03± 11.16	2.91±1.96	15.25±7.61
	Removed	228.65± 15.62	236.27± 16.07	1.55±0.49	9.17±2.37
Test statistics	F	0.02	0.00	0.49	0.61
	P	0.8910	0.9681	0.5172	0.4468

Table 5.34: Mean plot basal area increments (cm^2) of non-sal by litter treatments

Forest	Litter	Non-sal stand	Non-sal survivor	Ingrowth	Mortality
BH	Retained	17.75± 3.28	16.55± 3.22	1.61±0.43	1.11±1.10
	Removed	25.37± 5.24	24.76± 5.07	1.47±0.33	1.46±0.31
Test statistics	F	1.83	2.33	1.03	3.68
	P	0.1944	0.1442	0.8675	0.1130
RP	Retained	11.84± 4.46	20.20± 4.11	2.43±0.44	10.80±3.01
	Removed	3.84± 8.97	20.52± 3.73	2.30±0.62	18.98±7.96
Test statistics	F	0.72	0.65	0.03	0.97
	P	0.8544	0.4294	0.8729	0.3378

Summary of treatment effects on plot basal area increment:

- Lopping significantly affected mean plot basal area increment in three strata - survivors, sal-net and sal survivors - of Rapti. In all significant results, 40% and 60% lopping produced the highest plot basal area increments. No-lopping and 80% lopping showed similar increments in all three cases.

- Litter removal did not produce significant differences in basal area increment in any strata of either forest.

- No interaction effects were recorded between lopping and litter treatment in plot basal area increment.

5.4.2 Effects on plot volume

Treatment effects on plot volume increment are presented in Tables 5.35 through 5.40. Plot net (i.e. including ingrowth and deducting mortality) volume increments ranged from 83.5 to 99.9 dm^3 (16.7 to 20.0 m^3 ha^{-1}) in Basanta-hariyali and 81.0 to 110.6 dm^3 (16.2 to 22.1 m^3 ha^{-1}) in Rapti. In the case of survivors, the annual plot volume increments ranged from 85.4 to 102.7 dm^3 (17.1 to 20.5 m^3 ha^{-1}) in Basanta and 93.2 to 114.5 dm^3 (18.6 to 22.9 m^3 ha^{-1}) in Rapti.

Lopping effects

Lopping did not produce any significant differences in plot volume increments in any stratum in Basanta-hariyali, but produced significant results in four strata - survivors, sal-net, sal-survivors and non-sal-survivors - in Rapti (Tables 5.35 through 5.37). Groupings from Tukey's test based on 5% level of significance are presented in Figure 5.6. Ingrowth and mortality volumes did not show any significant F values in any strata of either forest.

Table 5.35: Mean plot volume increments (dm^3) of all species by lopping intensities

Forest	Lopping	Plot-net	Survivor	Ingrowth	Mortality
BH	0	84.98±6.90	85.36±6.91	0.87± 0.26	1.25± 0.76
	40	99.89± 5.67	101.50± 5.89	0.77± 0.32	2.39± 1.47
	60	96.44± 12.73	102.74± 13.60	0.43± 0.12	6.73± 5.18
	80	83.47± 3.69	85.99± 2.42	1.74 ± 0.86	4.26± 2.46
Test statistics	F	0.24	1.98	1.30	0.75
	P	0.8652	0.1525	0.3034	0.5397
RP	0	81.03± 8.59 b	93.46±5.63bc	2.09± 1.50	2.47± 0.55
	40	110.55± 8.84 a	114.47±4.90a	0.93± 0.31	3.06± 0.78
	60	106.70± 7.12 ab	108.48±5.05ab	0.58± 0.14	7.87± 3.26
	80	94.88± 8.54 ab	93.17±5.25c	0.69± 0.22	7.31± 2.74
Test statistics	F	2.59	3.98	0.79	1.79
	P	0.0832	0.0244	0.5186	0.1868
	Covariate F	n.s.	17.70	n.s.	n.s.
	P		0.0010		

Table 5.36: Mean plot volume increments (dm^3) of sal by lopping intensities

Forest	Lopping	Sal	Sal Survivor	Ingrowth	Mortality
BH	0%	78.37± 4.34	79.02± 4.46	0.47±0.20	1.13±0.65
	40%	93.66± 5.41	95.44± 5.81	0.44±0.21	2.23±1.38
	60%	90.79± 12.48	97.15± 13.17	0.25±0.06	6.61±5.17
	80%	73.23± 3.29	76.97± 2.38	1.47±0.89	4.20±2.47
Test statistics	F	0.22	0.10	1.32	0.75
	P	0.8818	0.9571	0.2972	0.5348
RP	0%	84.24±6.08b	84.89±5.29b	1.59±1.44	1.07±0.37
	40%	106.33± 5.23a	107.98±4.55a	0.42±0.23	1.92±0.61
	60%	101.48± 5.37a	103.98±4.67a	0.26±0.14	3.24±1.19
	80%	84.62±5.69b	87.06±4.95b	0.24±0.09	3.53±2.46
Test statistics	F	4.75	5.70	0.76	0.78
	P	0.0149	0.0063	0.5282	0.5216
	Covariate F	11.28	18.47	n.s.	n.s.
	P	0.0040	0.0009		

Table 5.37: Mean plot volume increments (dm^3) of non-sal by lopping intensities

Forest	Lopping %	Non-Sal net	Non-Sal Survivor	Ingrowth	Mortality
BH	**0**	6.61± 3.54	6.33± 3.49	0.39±0.09	0.73± (one plot only)
	40	6.23± 0.72	6.06± 0.58	0.33±0.19	0.48±0.22
	60	5.66± 1.37	5.59± 1.41	0.22±0.09	0.18±0.08
	80	9.24± 1.93	9.02± 1.92	0.28±0.09	0.11±0.06
Test statistics	**F**	0.13	0.10	0.39	4.60
	P	0.9397	0.9607	0.7960	0.0667
RP	**0**	7.33± 2.77	9.00± 1.07a	0.50±0.08	1.40±0.66
	40	5.64± 2.40	6.62± 1.06ab	0.50±0.17	1.14±0.39
	60	0.91± 3.46	4.06± 1.08b	0.32±0.07	4.63±2.38
	80	2.62± 1.88	6.01± 1.06ab	0.45±0.21	3.78±1.91
Test statistics	**F**	2.25	3.55	0.34	1.21
	P	0.1217	0.0385	0.8001	0.3332
	Covariate F	n.s.	30.19	n.s.	n.s.
	P		0.0001		

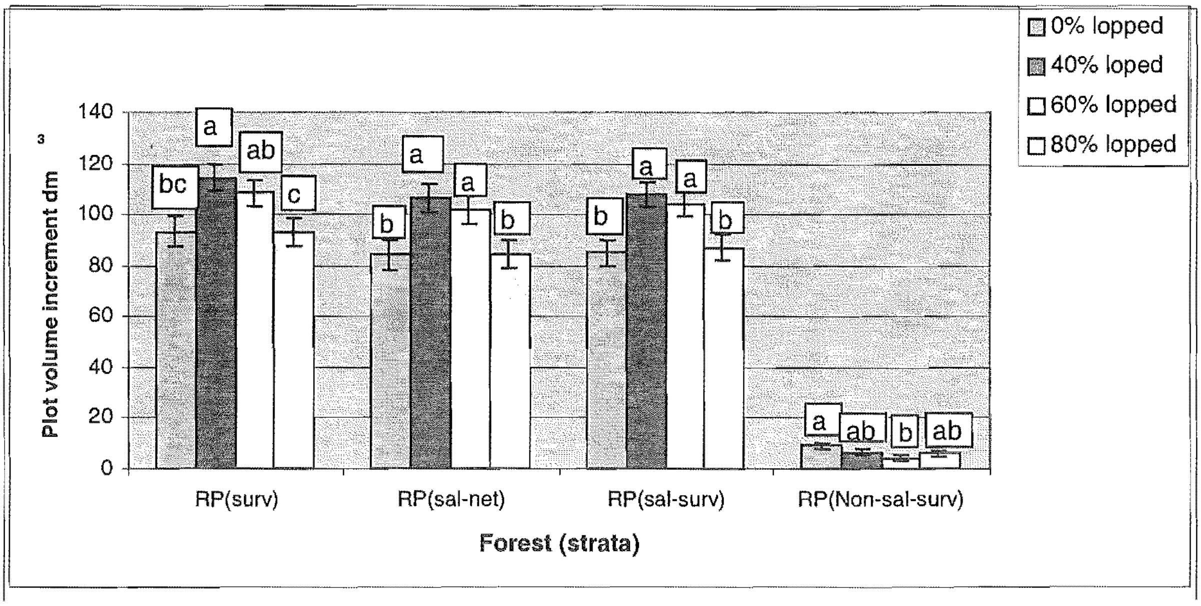

Figure 5.6: Plot stem volume increment for different strata of Rapti

Effects of litter removal on plot volume increment

Effects of ground-litter on plot volume increment are presented in Tables 5.38 through 5.40. In almost all cases, litter removal did not make any significant difference in the plot volume increment. However:

- except in survivors stratum of Basanta-hariyali, mean volume increment reduced with litter removal in all-species and sal strata;
- Ingrowth volume was reduced with litter removal in all cases; and
- Volume of mortality was increased with litter removal in all cases except in sal stratum of Rapti.

Table 5.38: Mean plot volume increments (dm^3) of all-species by litter treatments

Forest	Ground-litter	Net	Survivor	Ingrowth	Mortality
BH	Retained	92.14±5.41	93.46± 5.22	1.14± 0.47	2.46± 1.33
	Removed	90.25±6.15	94.34± 6.87	0.77± 0.18	4.86± 2.62
Test statistics	F	0.09	0.02	0.57	0.75
	P	0.3355	0.8984	0.4577	0.3993
RP	Retained	101.89±5.54	105.34± 5.07	1.40± 0.75	4.85± 1.39
	Removed	94.69±7.33	99.45± 7.27	0.74± 0.17	5.50± 1.86
Test statistics	F	0.33	0.24	0.72	0.10
	P	0.5738	0.6270	0.4077	0.7598
Covariate	n.s.	10.16 0.0044	n.s.	n.s.	n.s.

Table 5.39: Mean plot volume increments (dm^3) of sal by litter treatments

Forest	Ground-litter	Sal species	Sal Survivor	Ingrowth	Mortality
BH	Retained	86.39± 4.96	87.95± 4.83	0.84±0.47	2.39±1.33
	Removed	82.13± 5.95	86.35± 6.70	0.47±0.14	4.69±2.61
Test statistics	F	1.99	0.69	0.60	0.68
	P	0.1755	0.4159	0.4479	0.4199
RP	Retained	96.88± 5.50	98.84± 5.41	0.93±0.72	2.88±1.31
	Removed	91.45± 6.69	93.11± 6.78	0.33±0.12	2.00±0.48
Test statistics	F	0.12	0.09	0.65	0.46
	P	0.7342	0.7718	0.4295	0.5658

Table 5.40: Mean plot volume increments (dm^3) of non-sal by litter treatments

Forest	**Ground-litter**	**Non-sal**	**Non-sal survivor**	**Ingrowth**	**Mortality**
BH	Retained	5.75± 1.10	5.51± 1.08	0.32±0.10	0.24±0.24
	Removed	8.12± 1.77	7.99± 1.74	0.30±0.06	0.29±0.08
Test statistics	F	1.79	1.82	0.03	1.94
	P	0.1997	0.1938	0.8712	0.2227
RP	Retained	5.00± 1.76	6.50± 1.69	0.47±0.10	1.97±0.49
	Removed	3.24± 2.12	6.34± 1.33	0.41±0.10	3.50±1.52
Test statistics	F	1.41	2.11	0.21	0.95
	P	0.2530	0.1661	0.6554	0.3417

Summary of treatment effects on plot stem-volume increment

- Lopping showed no effects on volume increment in any stratum of Basanta-hariyali. Out of the four strata in which lopping significantly affected increment at the 5% significance, three strata (survivors, sal-net and sal survivors) of Rapti showed highest mean plot volume increment with 40% lopping. Sixty-percent lopping also produced significantly higher increment as compared to no-lopping and 80% lopping. As compared to no-lopping, even 80% lopping did not adversely affect plot volume increment.

- In the case of the non-sal-survivors stratum of Rapti, 60% lopping adversely affected the plot mean volume increment.

- Litter removal reduced the plot mean volume increment in general but none significantly at the 5% significance level.

- No interactions between lopping and litter treatments were present in plot mean volume increment.

5.4.3 Effects on ingrowth and mortality frequencies

Ingrowth and mortality frequencies for both forests are given in Tables 5.41 (all species) and 5.42 (sal). Neither main effects nor interactions were significant for ingrowth of all species or sal in either forest, except the interaction for sal in Basanta. Interaction between lopping and litter removal was found significant at the 5% level of significance in sal ingrowth at Basanta (χ^2= 10.65, p=0.0138).

Table 5.41: Ingrowth and mortality frequencies (all species)

		Basanta			Rapti		
	Lopping intensity	Litter-retained	Litter-removed	Total	Litter-retained	Litter-removed	Total
Ingrowth	0%	16	37	53	47	75	122
	40%	34	21	55	56	70	126
	60%	24	26	50	56	47	103
	80%	31	39	70	54	49	103
Total		**105**	**123**	**248**	**213**	**241**	**454**
Mortality	0%	9	3	12	77	47	124
	40%	13	18	31	56	105	161
	60%	13	23	36	102	106	208
	80%	20	24	44	102	105	207
Total		**55**	**68**	**123**	**337**	**363**	**700**

Table 5.42: Ingrowth and mortality frequencies (sal)

		Basanta			Rapti		
	Lopping intensity	Litter-retained	Litter-removed	Total	Litter-retained	Litter-removed	Total
Ingrowth	0%	7	24	31	15	34	49
	40%	16	13	29	16	30	46
	60%	17	17	34	23	23	46
	80%	24	26	50	25	15	40
Total		**64**	**80**	**144**	**79**	**102**	**181**
Mortality	0%	8	3	11	35	28	63
	40%	13	15	28	18	58	76
	60%	11	16	27	52	51	103
	80%	19	16	35	59	49	108
Total		**51**	**50**	**101**	**164**	**186**	**350**

The effect of lopping on mortality of all species (combined) in both forest was highly significant at the 5% level (χ^2= 15.76, p=0.0013 for Basanta, and χ^2= 30.87, p=0.000 for Rapti). In Basanta, the main effects were significant between 0% lopping and all other lopping intensities; tests did not show any differences among 40, 60 and 80% lopping. In Rapti, the interaction between lopping and litter removal on mortality was significant (χ^2= 20.81, p=0.0001). For sal mortality, only the main effect of lopping was significant in Basanta (χ^2= 11.28, p=0.0103), whereas lopping main effect (χ^2= 19.30, p=0.0002) and interaction with litter removal (χ^2= 19.90, p=0.0002) were highly significant in Rapti. Non-sal species showed lopping effect (χ^2= 14.78, p=0.0020) and interaction (χ^2= 11.01, p=0.0117) significant only in Rapti.

5.5 Treatment effects on growth in 1-1.37 m height class

No significant differences among treatments were found in collar-diameter, height, the cross-sectional area and stem volume increment of trees between 1 m and 1.37 m height in either forest.

5.6 Synopsis of results

Lopping treatment did not produce any significant differences in any variable in any strata in Basanta-hariyali. Lopping up to 80% of tree height did not adversely affect the growth of trees and stands as compared to 0% lopping, based upon one year's growth after lopping. Lopping, however, showed significant results in almost all variables in most of the strata of Rapti forest.

Main effects of lopping and litter removal on ingrowth (frequency, basal area and volume) were not significant in any strata in either forest. Only the interaction between lopping and litter removal showed significant effects on ingrowth frequencies for sal in Basanta; 80% lopping and litter-removal produced greatest frequency for sal ingrowth in Basanta. Interactions of lopping and litter-removal for ingrowth (basal area and volume) were not significant for either forest.

Main effects of lopping on mortality (frequency) of all species (combined) and sal were significant in Basanta; the increase in the lopping intensity the greater the mortality frequency in both of these strata in Basanta. Interactions between lopping and litter removal produced significant effects on mortality frequency of all-species, sal and non-sal strata in Rapti. Although treatments showed differential effects on mortality frequencies in both forests, the effects (main and interaction) were not significant for basal area and volume of mortality among treatments in either forest.

Effects of litter removal were insignificant in all strata of both forests. However, the consistent trend was growth reduction with litter removal.

In summary, the following are the immediate responses to lopping, based upon results from Rapti forest:

- Lopping in strata of sal-survivors (at 10% significance level), largest-diameter-trees and tallest-trees significantly (at 5% significance level) affected tree dbh increments. In these strata, the greater increments were in 40% lopping followed by 60% lopping. The lowest were in no-lopping in sal-survivors stratum, and in 80% in two other strata. Lopping up to 80% of tree height increased the mean-tree dbh growth rate, whereas 80% lopping adversely affected the dbh increment of dominant trees.

- Lopping affected tree basal area increment significantly at the 5% significance level in four strata (all-trees, sal, fattest and tallest) of Rapti. Forty-percent lopping produced significantly greater basal area increment than 0% lopping in the former two strata, and than 80% lopping in latter two strata. Lopping up to 60% of tree height increased the growth of trees in all four strata, but significantly only in the sal stratum.

- Forty percent lopping increased mean tree height increment, while other lopping intensities were not significantly different. Lopping up to 80% of tree height did not produce significant adverse effects in Rapti.

- In the case of tree volume increment, 40% lopping produced greatest increment in all strata. No-lopping showed lowest increment except tallest-tree and non-sal strata. It was only in tallest-tree stratum that 80% lopping adversely affected growth.

- In plot basal area too, 40% lopping produced greatest growth and no-lopping the lowest increment. Results were similar for plot-level stem volume increment.

Assessment of all variables in all strata indicated that 40% lopping followed by 60% lopping produced the greatest increments. In many cases, even 80% lopping produced greater increment than no-lopping treatments.

Summary of the significant effects of lopping treatment are presented in Table 5.43.

Table 5.43: Summary of the significant effects of lopping treatment

Lopping %	Tukey grouping for mean tree increment														Tukey grouping for mean plot increment of						
	dbh			basal area				height		volume					basal area			volume			
	RP (sal)	RP (fat)	RP (top)	RP (all)	RP (sal)	RP (fat)	RP (top)	RP (all)	RP (sal)	RP (all)	RP (sal)	RP (fat)	RP (top)	RP (non -sal)	RP (surv)	RP (sal-net)	RP (sal-surv)	RP (surv)	RP (sal-net)	RP (sal-surv)	RP (non-sal-surv)
0	b	ab	a	b	b	bc	ab	ab	b	b	b	b	a	a	b	b	b	bc	b	b	a
40	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	ab
60	ab	a	a	ab	a	ab	a	b	b	ab	a	ab	a	b	a	a	a	ab	a	a	b
80	ab	b	b	ab	ab	c	b	ab	ab	b	ab	ab	b	ab	b	ab	b	c	b	b	ab
F	2.61	8.73	8.15	4.87	6.45	7.21	5.64	4.58	4.36	3.28	3.35	3.96	6.13	4.45	5.66	5.82	9.97	3.98	4.75	5.70	3.55
P	.0811	.0008	.0011	.0112	.0034	.0020	.0062	.0141	.0188	.0449	.0422	.0239	.0047	.0165	.0077	.0069	.0006	.0244	.0149	.0063	.0385

all = all species; fat = based on 10 largest dbh trees per plot; net = survivors + ingrowth - dead; non-sal = all species excluding sal;
sal = only sal trees; surv = survivors; top = based on 10 tallest trees per plot;

CHAPTER VI. EFFECTS OF LOPPING AND LITTER REMOVAL ON REGENERATION

6.1 Regenerating species

Combining both sites, 177 species, 129 in 1997 and an additional 48 in 1998, were recorded in two regeneration censuses. Of the total species recorded at the two sites during the first census, 25 were absent in the second census. So, 152 species were recorded in 1998. Only 34 species (26%) were common to both sites in 1997, whereas 44 species (29%) were present at both sites in 1998. Numbers of species and frequencies by life form for both forests recorded in the two censuses are given in Table 6.1, and summarised in Figure 6.1 (species-wise details in Appendices II-IV).

Table 6.1: Details from regeneration censuses

Forest	Life-form	Number of individuals recorded in							
		1997		1998		lost after 1997		New in 1998	
		species	plants	species	plants	species	plants[1]	species	plants[1]
Basanta	Fern	3	1400	2	4036	1	7	-	-
	Grass	14	232	14	850	8	72	8	324
	Herb	27	1693	28	3998	10	411	11	1395
	Liana	12	48	16	108	1	1	5	15
	Shrub	10	802	12	409	1	15	3	15
	Tree	23	311	26	634	6	9	9	27
	Total	**89**	**4486**	**98**	**10035**	**27**	**515**	**36**	**1776**
Rapti	Fern	2	13	2	99	-	-	-	-
	Fungi	1	1	3	18	-	-	2	6
	Grass	9	432	11	1035	-	-	2	26
	Herb	20	1391	27	2869	1	49	8	334
	Liana	11	394	14	587	-	-	3	14
	Palm	2	476	2	624	-	-	-	-
	Shrub	6	176	7	214	1	8	2	108
	Tree	23	720	32	943	5	7	14	87
	Total	**74**	**3603**	**98**	**6389**	**7**	**64**	**31**	**575**
Combined	Fern	4	1413	3	4135	1	7	-	-
	Fungi	1	1	3	18	-	-	2	6
	Grass	19	664	19	1885	7	57	7	148
	Herb	37	3084	45	6867	7	126	15	1706
	Liana	16	442	20	695	1	1	5	14
	Palm	2	476	2	624	-	-	-	-
	Shrub	13	978	15	623	1	15	3	8
	Tree	37	1031	45	1577	8	13	16	97
	Total	**129**	**8089**	**152**	**16424**	**25**	**219**	**48**	**1979**

[1] Numbers in this column denote the number of plants of respective species indicated in the immediate left column only.

Frequencies increased over time for all life forms in both forests except shrubs in Basanta, which decreased in the second measurement. Major increases were in ferns (188%), grasses (266%) and herbs (136%), lianas (125%) and trees (104%) in Basanta, and grasses (139%) and herbs (106%) in Rapti. Ferns and fungi also increased many fold at Rapti, but the frequencies in the first year were low.

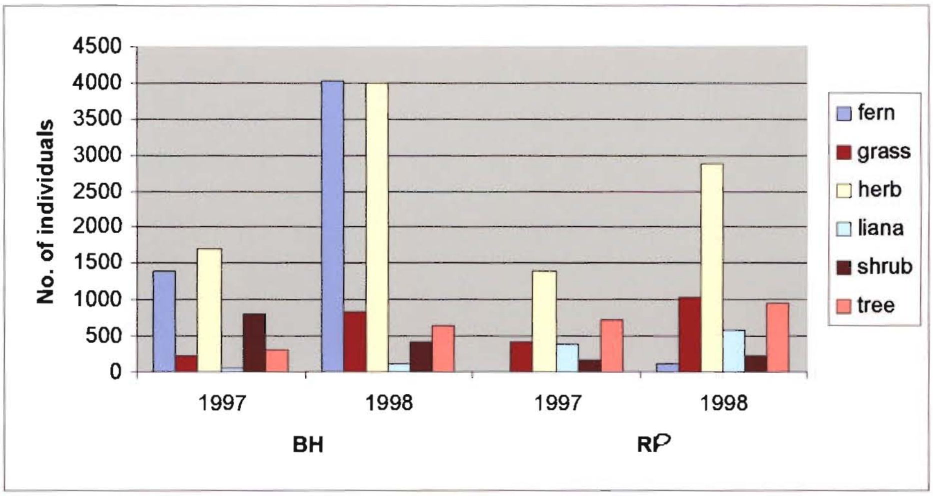

Figure 6.1: Regeneration frequencies over time by life-form

Species densities were categorised according to Raunkiaer's (1934) grouping on the basis of their presence in different percentages of total quadrates (Table 6.2) and plots (Table 6.3) for each measurement in both forests. The species movements from one group to another during the study period showed the dynamics of species frequencies in both forests (Table 6.4).

Table 6.2: Species' frequency groups based on their occurrences in 1 m^2 quadrats
(Figures in parentheses in 1997 and 1998 columns are lost and new species, respectively)

Group	Species (coded in Appendix I) recorded in			
	Basanta		Rapti	
	1997	1998	1997	1998
1-20%	2, 3, **(4, 6)**, 8, 9, 10, 12, 15, 16, **(17)**, 18, 19, 20, 23, 29, 31, 32, 33, 38, **(39)**, 40, 42, 46, 52, 53, 60, 61, 76, 78, **(81)**, 93, 94, **(95)**, 97, 103, 106, 109, 110, 111, 112, 117, 121, **(122)**, 126, 127, **(141, 142)**, 143, **(145)**, 147, **(150)**, 151, 152, 153, 154, **(155)**, 157, **(160)**, 161, **(162, 163, 165, 167, 168, 169, 170, 171)**, 172, 173, 175, **(179)**, 180, **(181, 182)**, 183, 184, **(187, 189)**	2, 3, 8, 9, 10, 12, 15, 16, 18, 19, 20, 23, **(25)**, 29, 31, 32, 33, **(37)**, 38, 40, 42, 46, **(47)**, 52, 53, **(55)**, 60, 61, **(66, 67, 72)**, 76, 78, **(88, 89)**, 93, 94, 106, 109, 110, 111, 112, **(113)**, 117, **(119)**, 121, **(128, 129)**, 140, 147, 151, 152, 153, 154, 157, 161, 172, 173, 175, 180, 183, 184, **(199, 208, 212, 217, 221, 222, 245, 246, 247, 251, 252, 253, 258, 259, 260, 261, 263, 266, 267, 268, 272)**	3, 4, **(8)**, 10, 12, 18, **(22)**, 23, 29, 32, **(34)**, 36, 40, 42, 43, 50, 52, 56, 58, **(64)**, 67, 70, 72, 81, **(83)**, 84, 87, 88, 92, 98, 99, 104, 105, 107, 109, 110, 111, 112, 113, 114, 116, 117, 118, 119, 121, 122, 123, **(124, 125)**, 126, 127, 128, 129, 130, 131, 132, 134, 135, 138	3, 4, **(9)**, 10, 12, 18, **(20)**, 23, 29, **(30, 31)**, 32, **(33)**, 36, **(38)**, 40, 42, 43, 50, 52, 56, **(60, 65, 66)**, 67, **(68)**, 70, 72, 81, 84, **(86)**, 87, 88, 92, 96, 98, 99, 104, 105, 110, 111, 112, 113, 114, 116, 117, 119, **(120)**, 121, 123, 126, 128, 129, 130, 131, 132, 134, 135, 138, **(139, 161, 163, 168, 194, 229, 242, 248, 249, 250, 256, 257, 265, 275, 276, 277, 279)**
21-40%	5, 77, 164	5, 97, 103, 143, 164, **(262)**	6, 7, 44, 69, 93, 95, 97, 103, 106	5, 6, 44, 69, 77, 93, 94, 95, 103, 106, 107, 122, 127, **(255)**
41-60%	**(44)**, 139, 146	77, 127, 146, 148	77, 78, 94	7, 58, 78, 97, 109, 118
61-80%	1, 134, 140, 148	126, 134, 139	102	102
81-100%	-	1, **(254)**	1, 96	1

Table 6.3: Species' frequency groups based on their occurrences in plots
(based on five 1-m^2 quadrates in a plot)

Group	Species recorded in			
	Basanta		Rapti	
	1997	1998	1997	1998
1-20%	2, 4, 6, 8, 9, 10, 12, 15, 16, 17, 18, 29, 31, 38, 39, 40, 42, 46, 52, 53, 61, 76, 78, 81, 93, 94, 95, 111, 112, 117, 121, 122, 126, 145, 147, 150, 151, 152, 153, 154, 155, 157, 160, 161, 162, 167, 170, 175, 180, 181, 182, 183, 184, 187, 189	2, 9, 10, 12, 16, 25, 29, 31, 37, 38, 40, 42, 46, 47, 52, 53, 55, 61, 66, 67, 72, 76, 78, 88, 89, 93, 94, 110, 111, 113, 117, 129, 151, 153, 154, 157, 183, 184, 199, 208, 212, 217, 221, 222, 246, 247, 260, 261, 263, 266, 267, 268, 272	3, 4, 8, 10, 18, 22, 23, 29, 34, 36, 42, 52, 56, 58, 64, 67, 81, 83, 84, 87, 92, 98, 104, 105, 110, 113, 116, 118, 119, 121, 123, 125, 127, 129, 130, 131, 134, 135, 138	3, 4, 9, 10, 18, 20, 31, 33, 38, 50, 60, 65, 66, 67, 68, 70, 81, 86, 87, 88, 92, 99, 104, 105, 110, 111, 112, 120, 123, 131, 138, 139, 161, 163, 168, 194, 229, 242, 248, 249, 250, 256, 257, 265, 275, 276, 277, 279
21-40%	3, 19, 20, 23, 32, 33, 60, 106, 109, 127, 142, 163, 165, 171, 172, 173, 179	3, 8, 15, 18, 19, 20, 32, 33, 60, 106, 109, 112, 119, 121, 140, 147, 152, 161, 172, 173, 180, 251, 252, 253	32,40, 43, 50, 70, 88, 99, 107, 109, 112, 117, 122, 126, 128, 132	5, 23,29, 30, 40, 42, 43, 52, 84, 88, 96, 98, 116, 117, 119, 121, 129, 130, 132, 134, 135
41-60%	5, 97, 103, 110, 141, 143, 169	5, 23, 103, 128, 143, 175, 245, 258	12, 72, 111, 114, 124	12,32, 36, 95, 113, 114, 126, 127, 255
61-80%	146, 164, 168	97, 127, 164, 259, 262	126, 7, 44, 103, 106	6, 44, 69, 72, 77, 94, 107, 128
81-100%	1, 44, 77, 134, 139, 140, 148	1, 77, 126, 134, 139, 146, 148, 254	1, 69, 77, 78, 93, 94, 95, 96, 97, 102	1, 7, 58, 78, 93, 97, 102, 103, 106, 109, 118, 122

Table 6.4: Summary of Species' frequency groups based on their occurrences in quadrats and plots

Frequency group	Species recorded in							
	Basanta				Rapti			
	1997		1998		1997		1998	
	Quadrat	Plot	Quadrat	Plot	Quadrat	Plot	Quadrat	Plot
1-20%	79	55	83	53	59	39	76	48
21-40%	3	17	6	24	9	15	14	21
41-60%	3	7	4	8	3	5	6	9
61-80%	4	3	3	5	1	5	1	8
81-100%		7	2	8	2	10	1	12
	89	89	98	98	74	74	98	98

Densities and numbers of individuals by species in the area studied are presented in Appendix V. Abundance classes based on species density showed the trend of increasing species in the second measurement (Table 6.5).

Table 6.5: Number of species by abundance class

Abundance class (individuals ha^{-1})	Number of species			
	Basanta		Rapti	
	1997	1998	1997	1998
High (> 16667)	7	10	6	8
Medium (4167-16667)	3	10	8	16
Low (833 - 4167)	20	23	23	33
Rare (83 - 833)	59	55	37	41
Total species #	89	98	74	98

6.2 Treatment effects on regeneration frequencies

Tables 6.1 through 6.5 showed changes in occurrences and frequencies of species in two censuses separated by a one-year period. These results were tested for treatment effects on regeneration frequencies of individuals. The results from analysis of frequencies of individuals in two sites showed significant differences between sites for all compared groups of the census (Table 6.6), and two groups - fungi and palms - were recorded only at Rapti.

Table 6.6: Comparison of frequencies changes of individuals between the two sites

Changes in frequency in	Chi-Square	Probability
Total	880.56	0.0000
Trees	18.11	0.0000
Non-tree	872.95	0.0000
Sal	79.15	0.0000
Non-sal	47.42	0.0000
Ferns	984.29	0.0000
Grasses	0.18	0.6677
Herbs	177.84	0.0000
Lianas	62.48	0.0000
Shrubs	Frequencies for shrubs have decreased in Basanta, so not tested.	
Fungi	Only in Rapti, so not tested.	
Palms	Only in Rapti so not tested.	

Thus site-specific tests were performed for all subsets. The following sets and subsets of census data were analysed with a log-linear model using maximum-likelihood analysis, and tested by Chi-square values and probabilities:

Total frequency change (including all life forms);

Frequency change by life form;

Frequency change in sal.

6.2.1 Treatment effects on total frequency change

Two-way figures of changes in total frequencies for both forests are given in Tables 6.7 (Basanta) and 6.8 (Rapti). Main effects and interactions between lopping and litter removal showed highly significant response in total frequency changes at Basanta. Lopping effect showed (χ^2_{3df}=447.51 and p≤0.0001) larger effects than interaction (χ^2_{3df}=214.18 and p≤0.0001) and litter removal effects (χ^2_{1df} =26.33 and p≤0.0001). Plots with 60% lopping and litter-removed produced the highest absolute frequency increase.

Table 6.8 showed a negative in one of the cells in Rapti, and this situation disqualified for CATMOD procedure. Removing herb group from the data met the requirements for CATMOD procedure (Table 6.9). CATMOD procedure showed main effects (χ^2_{3df} =120.68 and p≤0.0000 for lopping, and χ^2_{1df} =187.92 and p≤0.0000 for litter removal), and interaction highly significant (χ^2_{3df} =78.31 and p≤0.0000). Litter removal significantly influenced frequency increase. Plots under 80% lopping and litter-removed showed the highest proportional frequency increase, but 60% lopped and litter-removed plots produced the highest absolute increase.

Table 6.7: Two-way combination of levels for total frequency change in Basanta

Lopping intensity %	litter retained 1997	litter retained 1998	litter retained change absolute	litter retained change proportional	litter removed 1997	litter removed 1998	litter removed change absolute	litter removed change proportional	Change in 30 m^2
0	502	1061	559	1.11	518	807	**289**	0.56	**848**
40	478	1070	592	1.24	573	1306	733	1.28	1325
60	448	1209	**761**	1.70	760	2003	**1243**	1.64	**2004**
80	776	1277	**501**	0.65	431	1302	871	2.02	1372
Total	2204	4617	**2413**	1.09	2282	5418	**3136**	1.37	5549

(Number of individuals in 15 m^2 in)

Table 6.8: Two-way combination of levels for total frequency change in Rapti

Lopping Intensity %	litter retained 1997	litter retained 1998	litter retained change absolute	litter retained change proportional	litter removed 1997	litter removed 1998	litter removed change absolute	litter removed change proportional	Change in 30 m^2
0	543	610	67	0.12	482	1050	568	1.18	635
40	582	556	**-26**	-0.04	367	620	**253**	0.70	**227**
60	466	604	138	0.30	402	1281	**879**	2.19	**1017**
80	377	604	**227**	0.60	384	1064	680	1.77	907
Total	1968	2374	**406**	0.21	1635	4015	**2380**	1.46	2786

(Number of individuals in 15 m^2 in)

Table 6.9: Two-way combination of levels for total (excluding herbs) frequency change in Rapti

Lopping	litter retained 1997	litter retained 1998	litter retained change absolute	litter retained change proportional	litter removed 1997	litter removed 1998	litter removed change absolute	litter removed change proportional	Change in 30 m^2
0	303	368	65	0.21	301	520	219	0.73	284
40	280	329	**49**	0.18	258	361	**103**	0.40	**152**
60	280	375	95	0.34	255	724	**469**	1.84	**564**
80	260	397	**137**	0.53	275	446	171	0.62	308
Total	1123	1469	**346**	0.31	1089	2051	**962**	0.88	1308

(Number of individuals in 15 m^2 in)

In both cases, 60% lopping and litter-removed plots demonstrated highest absolute increase of regeneration frequencies, and frequencies were 668000 ha^{-1} in Basanta and 188000 ha^{-1} (excluding herbs) in Rapti.

6.2.2 Frequency changes in trees (all tree species including sal)

Two-way figures of changes in frequencies of trees for Basanta are given in Table 6.10. Lopping produced highly significant (χ^2_{3df}=21.79, p≤0.0001) results in regeneration of tree species in Basanta, and all lopping intensities increased regeneration over the not-lopped treatment. Forty-percent lopping produced the greatest change. Also litter removal significantly (χ^2_{1df} =3.90, p≤0.0483) increased tree regeneration in Basanta. Interactions between lopping and litter treatments were not significant at the 5% significance level for tree group frequency change in Basanta.

Table 6.10: Two-way combination of levels for tree frequency change in Basanta

Lopping Intensity %	Number of individuals in 15 m^2 in								Total change in 30 m^2
	litter retained				litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	45	67	**22**	0.49	54	83	**29**	0.54	**49**
40	36	82	**46**	1.23	24	88	**64**	2.67	**110**
60	38	81	43	1.13	31	77	46	1.48	89
80	50	82	32	0.64	33	74	41	1.24	73
Total	169	312	**143**	0.85	142	322	**180**	1.27	

Two-way figures of changes in frequencies of trees for Rapti are given in Table 6.11. Because of a decrease in one of the records for tree group frequencies of Rapti, the CATMOD procedure was run separately for lopping and litter treatment, and both were highly significant (χ^2_{3df} =32.93, p≤0.0000 for lopping and χ^2_{1df}=48.48 p≤0.0000 for litter treatment). Additionally, 25 was added to each record of absolute-change, so that the negative record was marginally positive meeting the condition for the CATMOD procedure. The analysis showed that the main effects of lopping and litter treatments were significant (χ^2_{3df} =7.89, p≤0.0483) and highly significant (χ^2_{1df} =16.91, p≤0.0000), respectively. Interactions between lopping and litter treatments were highly significant (χ^2_{3df} =21.52, p≤0.0001). Proportional change was greatest at 80% lopping with litter retained for tree group frequency change in Rapti forest.

Table 6.11: Two-way combination of levels for tree frequency change in Rapti

Lopping Intensity %	Number of individuals in 15 m^2 in								Change in 30 m^2
	litter retained				litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	100	141	41	0.41	162	138	**-24**	-0.15	**17**
40	66	88	22	0.33	88	125	**37**	0.42	59
60	72	117	45	0.62	67	97	30	0.45	**75**
80	74	132	**58**	**0.78**	91	105	14	0.15	72
total	312	478	**166**	0.53	408	465	**57**	0.14	

Forty-percent lopping with litter removal (but interaction is not significant) produced the highest regeneration of tree species in Basanta; 80% lopping and litter-retained treatment produced highest frequencies for tree species regeneration increase in Rapti. Regeneration increases, as results of these treatments were 36667 individuals ha^{-1} and 38667 individuals ha^{-1} in Basanta and Rapti, respectively.

6.2.3 Changes in frequency of sal

Tables 6.12 and 6.13 show two-way frequencies changes in sal for Basanta and Rapti forests, respectively. Lopping was highly significant (χ^2_{3df}=11.58, p≤0.0000) to sal regeneration in Basanta, and litter removal was significant (χ^2_{1df} =5.04, p≤0.0247). Forty-percent lopping produced the greatest absolute and proportional sal regeneration increases at Basanta. Litter removal increased frequency of sal regeneration at Basanta. No interactions between lopping and litter treatments were significant at the 5% significance level for sal regeneration in Basanta.

Table 6.12: Two-way combination of levels for total frequency change of sal in Basanta

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	litter retained				litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	38	57	**19**	0.50	44	74	**30**	0.68	**49**
40	30	67	**37**	1.23	15	65	**50**	3.33	**87**
60	30	66	36	1.20	21	60	39	1.86	75
80	45	72	27	0.60	27	63	36	1.33	63
Total	143	262	**119**	0.83	107	262	**155**	1.45	

To make all cells positive for the Rapti data, 16 was added to all cells to meet the requirements for the CATMOD procedure. The main effect of lopping was highly significant (χ^2_{3df}=16.90 and p≤0.0007), but not the main effect of litter removal (χ^2_{1df} =0.11 and p≤0.7457). Although the interaction was significant (χ^2_{3df}=9.83 and p≤0.0201), the main effect was greater than the interaction effects. Sixty-percent lopping and litter-removed plots showed greatest sal regeneration increases at Rapti.

Table 6.13: Two-way combination of levels for total frequency change of sal in Rapti

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	litter retained				litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	53	58	5	0.09	114	99	-15	**-0.13**	**-10**
40	44	48	4	**0.09**	45	60	15	0.33	19
60	28	44	16	**0.57**	34	69	35	**1.03**	**51**
80	33	52	19	0.58	44	49	5	0.11	24
Total	158	202	**44**		237	277	**40**		

6.2.4 Changes in frequency of the non-tree individuals

Two-way frequency tables for the non-tree group are given in Tables 6.14 (Basanta) and 6.15 (Rapti). Main effects and interaction between lopping and litter treatments were highly significant in Basanta. Lopping main effect (χ^2_{3df} =446.89, p≤0.0000) was larger than the interaction (χ^2_{3df} =228.10, p≤0.0000). At Basanta, lopping increased frequency more in litter-removed plots than in the litter-retained ones. Litter removal (χ^2_{1df} =21.46, p≤0.0000) increased frequency more with 60% lopping than for other lopping intensities. Proportional change was highest in 80% lopping and litter-removed treatments for non-tree group frequency changes in Basanta.

A decrease in one of the cells for Rapti meant that a full CATMOD model could not be run. Separate analyses showed both treatments highly significant (χ^2_{3df} =456.04, p≤0.0000 for lopping and χ^2_{1df} =1120.88, p≤0.0000 for litter). Litter removal resulted in greater regeneration increase of non-tree species in Rapti.

To make all cells positive, 49 was added to each cell for non-tree group frequency change in Rapti. The main effects and interactions were highly significant. However, the effect of litter treatment (χ^2_{1df} =887.43, p≤0.0000) was highest followed by lopping treatment (χ^2_{3df} =245.75, p≤0.0000), and the interaction effect was the lowest (χ^2_{3df} =55.88, p≤0.0000). Interaction of 60% lopping and litter-removed treatment resulted in the greatest frequency change of non-tree group regeneration in Rapti.

Table 6.14: Two-way combination of levels for non-tree frequency change in Basanta

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	Litter retained				Litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	457	994	537	1.18	464	724	**260**	0.56	**797**
40	442	988	546	1.24	549	1218	669	1.22	1215
60	410	1128	**718**	1.75	729	1926	**1197**	1.64	**1915**
80	726	1195	**469**	0.65	398	1228	830	2.09	1299
change	2035	4305	**2270**	1.12	2140	5096	**2956**	1.38	

Table 6.15: Two-way combination of levels for non-tree frequency change in Rapti

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	Retained				removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	443	469	26	0.06	320	918	598	1.97	624
40	516	468	**-48**	-0.09	279	495	**216**	0.77	**168**
60	394	487	93	0.24	335	1184	**849**	2.53	**942**
80	303	472	**169**	0.56	293	959	666	2.27	835
change	1656	1896	**240**	0.14	1227	3556	**2329**	1.90	

Thus, 60% lopping and litter-removed plots showed highest absolute increase of non-tree species regeneration in both forests. However, 80% lopping and litter-removed showed higher proportional increase for Basanta. On the basis of absolute increase, treatments increased the regeneration 798000 individuals ha^{-1} and 566000 individuals ha^{-1} in Basanta and Rapti, respectively.

6.2.5 Changes in frequency of ferns

Ferns were more frequent at Basanta in 1998 than 1997 (Table 6.16). Although lopping and litter interaction were highly significant (χ^2_{3df}=34.95 and p≤0.0000) to fern increase at Basanta, the lopping effect (χ^2_{3df}=107.00 and p≤0.0000) was larger than that of the interaction. Lopping produced greater increases in frequency in litter-removed plots than in the litter-retained. Litter-removed treatments changed frequencies significantly (χ^2_{1df} =8.36 and p≤0.0034), and increased the frequency in 60%

lopping more than in other loping intensities. Sixty-percent lopping and litter-removed plots produced the greatest frequency increase in fern at Basanta.

Table 6.16: Two-way combination of levels for fern frequency change in Basanta

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	litter retained				litter removed				
	1997	1998	Increment		1997	1998	Increment		
			absolute	proportional			absolute	proportional	
0	150	386	**236**	1.57	161	401	**240**	1.49	**476**
40	175	450	275	1.57	165	471	306	1.85	581
60	175	501	326	1.86	289	807	**518**	1.79	**844**
80	132	521	**389**	2.95	153	499	346	2.26	735
Total	632	1858	**1226**	1.94	768	2178	**1410**	1.84	

The same model could not run for Rapti, as seven cells contained zero values. The model used was without interaction, and both lopping and litter treatments showed highly significant effects (χ^2_{3df} =37.98, p≤0.0000 for lopping, and χ^2_{1df}=17.11, p≤0.0000 for litter). However, an additional test was performed on 1998 records (i.e., second measurement), and it showed lopping highly significant (χ^2_{3df} =38.68 and p≤0.0000) and interaction significant (χ^2_{3df} =14.43 and p≤0.0024). The main effect of litter treatment was not significant (χ^2_{1df} =0.03 and p≤0.8529). Not-lopped and litter-retained plots showed greatest frequency increase. However, results were inconclusive for Rapti, as many cells recorded zero.

Table 6.17: Two-way combination of levels for fern frequency change in Rapti

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	litter retained				litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	0	36	36		8	17	9		45
40	5	0	-5		0	4	4		-1
60	0	2	2		0	6	6		8
80	0	30	30		0	4	4		34
Total	5	68	63		8	31	23		

6.2.6 Changes in frequency of grasses

Frequencies of grass group for both forests are presented in Tables 6.18 (Basanta) and 6.19 (Rapti). In Basanta, main effects of lopping and litter were highly significant (χ^2_{3df} =45.93 and p≤0.0000) and significant (χ^2_{1df} =9.53 and p≤0.0020) respectively, and interactions between treatments were highly significant (χ^2_{3df} =162.20, p≤0.0000). The plots under 60% lopping and litter-removed treatment produced highest frequency change in grasses.

Table 6.18: Two-way combination of levels for grasses frequency change in Basanta

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	Retained				removed				
	1997	1998	change absolute	change proportional	1997	1998	change absolute	change proportional	
0	40	132	**92**	2.30	17	30	**13**	0.76	105
40	29	47	**18**	0.62	48	125	77	1.60	**95**
60	7	37	30	4.29	38	277	**238**	6.26	**268**
80	33	112	79	2.39	20	90	70	3.50	149
Total	109	328	**219**	2.01	123	522	**398**	3.24	

To render all cells positive, 31 was added to each cell to meet the requirement of the CATMOD procedure for Rapti. The main effects and interactions of lopping and litter treatments were highly significant (χ^2_{3df}=51.87 and p≤0.0000 for lopping, χ^2_{1df}=213.31 and p≤0.0000 for litter treatment, and χ^2_{3df} =67.88 and p≤0.0000 for interaction). Litter removal contributed significantly to frequency increases in grasses at Rapti. Lopping to 60% of tree height and litter removal gave the greatest frequency increase in grasses.

Table 6.19: Two-way combination of levels for grasses frequency change in Rapti

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	Retained				removed				
	1997	1998	change absolute	change proportional	1997	1998	change absolute	change proportional	
0	49	19	**-30**	-0.61	52	207	155	2.98	125
40	69	75	6	0.08	63	72	**9**	0.14	15
60	74	51	-23	-0.31	59	404	**345**	5.85	322
80	37	45	**8**	0.22	29	162	133	4.59	125
Total	229	190	**-39**	-0.17	203	845	**642**	3.16	

6.2.7 Changes in frequency of herbs

Tables 6.20 and 6.21 give the detail of frequency changes of herbs at Basanta and Rapti, respectively. In Basanta, main effects and interaction of lopping and litter treatments were highly significant (χ^2_{3df} =381.94 and p≤0.0000 for lopping, χ^2_{1df} =11.56 and p≤0.0007 for litter, and χ^2_{3df} =300.57, p≤0.0000 for interaction). Lopping contributed more than litter removal for frequency increases of herb species at Basanta. Eighty-percent lopping and litter removal produced greatest proportional frequency increase in herbs, whereas absolute increase was greatest at 60% with litter removal.

Table 6.20: Two-way combination of levels for herb frequency changes in Basanta

Lopping Intensity %	Number of individuals in 15 m² in								Change in 30 m²
	Litter retained				Litter removed				
	1997	1998	change absolute	change proportional	1997	1998	change absolute	change proportional	
0	177	397	220	1.24	191	241	**50**	0.26	**270**
40	117	435	**318**	2.72	224	547	323	1.44	641
60	151	551	**400**	2.65	304	783	**479**	1.58	**879**
80	421	478	57	0.14	108	566	458	4.24	515
Total	866	1861	**995**	1.15	827	2137	**1310**		

The presence of one negative cell prevented using a full CATMOD model in Rapti, and lopping and litter treatments were tested separately. Main effects of lopping and litter treatments were highly significant (χ^2_{3df}=309.98 and p≤0.0000 for lopping, and χ^2_{1df}=575.79 and p≤0.0000 for litter).

Additionally, 76 was added to each cell to meet the conditions for the CATMOD procedure for Rapti. Main effects of lopping and litter were highly significant (χ^2_{3df}=133.71 and p≤0.0000 for lopping, and χ^2_{1df}=582.61 and p≤0.0000 for litter), and interaction between treatment was significant (χ^2_{3df}=13.52 and p≤0.0036). Plots with 80% lopping and litter removal produced the greatest increase in frequency of herbs at Rapti.

Table 6.21: Two-way combination of levels for herb frequency changes in Rapti

Lopping Intensity %	Number of individuals 15 m² in								Change in 30 m²
	Litter retained				Litter removed				
	1997	1998	change absolute	change proportional	1997	1998	change absolute	change proportional	
0	240	242	2	0.01	181	530	349	1.93	351
40	302	227	**-75**	-0.25	109	259	**150**	1.38	**75**
60	186	229	43	0.23	147	557	410	2.79	453
80	117	207	**90**	0.77	109	618	**509**	4.67	**599**
Total	845	905	60	0.07	546	1964	1418	2.60	

6.2.8 Changes in frequency of lianas

Neither main effects (χ^2_{3df}=3.49 and p≤0.3225 for lopping and χ^2_{1df}=0.01 and p≤0.9067 for litter) nor interaction (χ^2_{3df}=5.52 and p≤0.1375) were significant for changes in liana frequencies at Basanta.

Table 6.22: Two-way combination of levels for liana frequency changes at Basanta

Lopping Intensity %	Number of individuals 15 m² in								Change in 30 m²
	Litter retained				Litter removed				
	1997	1998	change absolute	change proportional	1997	1998	change absolute	change proportional	
0	7	18	11	1.57	6	9	3	0.50	14
40	6	12	6	1.00	8	17	9	1.13	15
60	6	10	4	0.67	10	17	7	0.70	11
80	2	11	9	4.50	3	14	11	3.67	20
Total	21	51	30	1.43	27	57	30	1.11	

Frequency change of lianas at Rapti include two decreases, so lopping and litter treatments were tested separately in CATMOD procedure. Effects of lopping and litter were highly significant (χ^2_{3df} =56.68 and p≤0.0000) and significant (χ^2_{1df}=6.28 and p≤0.0122), respectively.

Additionally, six was added to each cell to meet the requirements for the CATMOD procedure in regeneration census data for Rapti. Main effects of lopping and litter were highly significant (χ^2_{3df} =45.41 p≤0.0000), and significant (χ^2_{1df}=10.53 p≤0.0012), respectively. Although the interaction was highly significant (χ^2_{3df}=35.46 p≤0.0000), the lopping effect was greater than the interaction. Eighty-percent lopping and litter-removed plots produced the highest absolute change, but not-lopped and litter removed plots produced the highest proportional change.

Table 6.23: Two way combination of levels for liana frequency changes at Rapti

Lopping intensity %	Number of individuals in 15 m^2 in								Change in 30 m^2
	litter retained				litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	57	52	-5	-0.09	24	59	35	1.46	30
40	66	62	-4	-0.06	52	65	13	0.25	9
60	52	105	53	1.02	52	73	21	0.40	74
80	49	84	35	0.71	42	87	45	1.07	80
Total	224	303	79	0.35	170	284	114	0.67	

6.2.9 Changes in frequency of palms

No palms were recorded at Basanta, so the two-way frequency table is presented only for Rapti (Table 6.24). To meet the requirements for CATMOD procedure, 20 was added to each cell. Lopping effect was highly significant (χ^2_{3df} =22.20 p≤0.0001), whereas litter showed significant effects (χ^2_{1df} =9.37 p≤0.0022). Interactions between lopping and litter treatments were significant (χ^2_{3df} =12.53, p≤0.0058) for palm regeneration in Rapti. Lopping to 60% of tree height and litter-removed treatments resulted in the greatest palm frequency.

Table 6.24: Two-way combination of levels for palm frequency changes at Rapti

Lopping intensity %	Number of individuals in 15 m^2 in								Change in 30 m^2
	litter retained				litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	56	77	21	0.38	39	64	25	0.64	46
40	40	47	7	0.18	38	71	33	0.87	40
60	68	82	14	0.21	58	120	62	1.07	76
80	91	96	5	0.05	86	67	-19	-0.22	-14
Total	255	302	47	0.18	221	322	88		

6.2.10 Changes in frequency of shrubs

In all treatment levels for frequency of shrub regeneration at Basanta, frequencies of the first census (1997) were greater than those of the second census (1998). So subtracting first record from the second resulted in a decrease, and the CATMOD procedure showed error. So, the analysis was conducted by subtracting second census figure from the first, and the results are presented in Table 6.25.

The main effect of lopping was highly significant (χ^2_{3df}=19.43, p≤0.0002), and litter treatment was not significant (χ^2_{1df}=0.28, p≤0.5940) for shrub regeneration in Basanta. Interaction between lopping and litter treatment was significant (χ^2_{3df} =14.19, p≤0.0027). Not-lopped and litter-retained plots resulted in the smallest decrease in shrub regeneration in the second census.

Table 6.25: Two-way combination of levels for shrub frequency changes at Basanta

Lopping intensity %	Number of individuals in 15 m² in								Change in 30 m²
	Litter retained				Litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	83	61	-22	-0.27	89	43	-46	-0.52	**-68**
40	115	44	-71	-0.62	104	58	-46	-0.44	-117
60	71	29	-42	-0.59	88	42	-46	-0.52	-88
80	138	73	-65	-0.47	114	59	-55	-0.48	**-120**
Total	407	207	**-200**	-0.49	395	202	**-193**	-0.49	

Eight was added to each cell of shrub regeneration data of Rapti (Table 6.26). Lopping produced significant (χ^2_{3df} =15.97, p≤0.0012) frequency change of shrub regeneration in Rapti, but the litter treatment was not significant (χ^2_{3df}=0.20, p≤0.6524). However, the interaction between lopping and litter treatment was highly significant (χ^2_{3df}=21.07, p≤0.0001).

Table 6.26: Two-way combination of levels for shrub frequency change in Rapti

Lopping intensity %	Number of individuals 15 m² in								Change in 30 m²
	Litter retained				Litter removed				
	1997	1998	change		1997	1998	change		
			absolute	proportional			absolute	proportional	
0	41	39	-2	-0.05	15	35	20	1.33	18
40	34	52	18	0.53	17	23	6	0.35	24
60	14	12	-2	-0.14	19	23	4	0.21	2
80	9	10	1	0.11	27	20	-7	-0.25	-6
Total	98	113	15	0.15	78	101	23	0.29	

6.3 Synopsis of results

Main effects and interaction and their significance levels are presented in Table 6.27. The following are evident from the table:

- Lopping effects were highly significant in all cases in both forests, except for lianas in Basanta.

- Litter effects were also significant at different levels for most of the cases, excluding liana and shrub groups of Basanta, and sal and shrub group of Rapti.
- Lopping and litter interactions were significant at different levels in all but tree, sal, and liana groups at Basanta, and all except fern at Rapti.

Table 6.27: Summary for significance level

	Basanta			Rapti		
Level	Lopping (Lop)	Litter (Lit)	Lop*Lit	Lopping	Litter	Lop*Lit
Total	***	***	***	***	***	***
Tree	***	*	Ns	**	***	***
Non-tree	***	***	***	***	***	***
Sal	**	*	Ns	***	Ns	*
Fern	***	**	***	***	***	Ns
Grass	***	**	***	***	***	***
Herb	***	***	***	***	***	**
Liana	Ns	Ns	Ns	***	**	***
Palm				***	**	**
Shrub	***	Ns	**	**	Ns	***

Ns- Not significant, *- significant at 5% level, ** - significant at 1% level, *** - Significant at .1% level.

Matrix for interaction (indicating maximum and minimum frequencies recorded) is presented in Table 6.28. Most of the maxima were in plots with 60% lopping and litter-removed, and minima in cells not-lopped with litter-removed (Table 6.29).

Table 6.28: Matrix of maximum and minimum frequency for interacting variables

Forest	Treatments	No lopping	40% lopping	60% lopping	80% lopping
Basanta	Litter retained	Fern =min Sal = min Shrub =max Tree = min			Shrub =min
	Litter removed	Total =min Non-tree =min Grass =min Herb =min	Sal =max Tree =max	Total =max Non-tree =max Fern =max Grass =max Herb =max	
Rapti	Litter retained	Liana =min Grass =min	Total =min Non-tree =min Herb =min		Tree = max
	Litter removed	Sal =min Shrub =max Tree =min		Total = max Sal =max Palm =max Non-tree =max Grass =max	Liana =max Palm =min Shrub =min Herb =max

Table 6.29: Summary of maximum and minimum increase by life-form

Life-form	Treatment levels for			
	Basanta		Rapti	
	Maximum increase	Minimum increase	Maximum increase	Minimum increase
Total	60% lopping litter-removed	0% lopping litter-removed	60% lopping litter-removed	40% lopping litter-retained
Tree	40% lopping litter-removed	0% lopping litter-retained	80% lopping litter-retained	0% lopping litter-removed
Non-tree	60% lopping litter-removed	0% lopping litter-removed	60% lopping litter-removed	40% lopping litter-retained
Sal	40% lopping litter-removed	0% lopping litter-retained	60% lopping litter-removed	0% lopping litter-removed
Fern	60% lopping litter-removed	0% lopping litter-retained	NA	NA
Grass	60% lopping litter-removed	0% lopping litter-removed	60% lopping litter-removed	0% lopping litter-retained
Herb	60% lopping litter-removed	0% lopping litter-removed	80% lopping litter-removed	40% lopping litter-retained
Liana	NS	NS	80% lopping litter-removed	0% lopping litter-retained
Shrub	0% lopping litter-retained	80% lopping litter-retained	0% lopping litter-removed	80% lopping litter-removed

CHAPTER VII. INDIGENOUS KNOWLEDGE OF MULTIPLE PRODUCTS IN SAL FORESTS

This chapter deals with indigenous knowledge of sal forests, mainly focusing on aspects of forest products, and silvicultural characteristics of the species concerned. The study is based on information collected mainly from the users of Basanta and Rapti community forests, supplemented by information from Sugure community forest users group.

The study used open-ended questions to identify forest products used by local users, and to explore the range of ethnosilvicultural knowledge among users. As the users themselves selected the key informants, no sampling procedures were followed to select them, i.e., key informants. Products and knowledge statements were not prioritised, and all statements were taken as of equal importance. Although statistical validity was limited, the chi-square tests of association (SPSS, 1999) were performed to understand the relationships between knowledge and socio-economic category of users.

7.1 Knowledge sources

Ethnically, Basanta and Rapti CFUGs have six categories (Table 3.3). While selecting key informants, it was understood that all categories except for the people from the Tarai had some knowledge of multiple products from their forest. Mostly the people from the Tarai were from the business community, and had no experience of forests from users' perspectives. So no person from this group was nominated to be a key informant.

Occupationally, users were categorized on the basis of their main source of living (Table 3.3). The series of discussions with users revealed that wages, farming and business were the main categories for income sources. Users selected key informants from the groups of wage-earning and farming groups, and excluded the business group. Users' understanding revealed that the business group had little knowledge of forestry management issues, although they may have had some information on the issue of marketing.

Landholding was easily observable variable in both users groups. The members of both users groups were classified in three categories - those with no land, with land less than 0.25 ha, and with land more than 0.25 ha. The no-land category included landless users, but many of them in Rapti were cultivating forestland illegally.

Elite people in all categories were found holding either key positions of major political parties or employed in a relatively high position. Although some of them were initially considered informative, they were later replaced by common people who were found to be more informative than the elite.

Gender and age were always a matter of concern while selecting key informants. Two age classes i.e., between 20 and 50 years, and over 50 years, were considered valid in both users groups (Table 7.1).

Table 7.1: Categories represented by key informants
(Number key informants in parentheses)

Ethnic group	Occupation	Land	Age	Gender
Magar (35)	Wage-earning (62)	No land (29)	20-50 years (31)	Female (50)
Brahman/Chhetri or B/C (31)	Farming (49)	<.25 ha (62)	Above 50 years (80)	Male (61)
Occupational (18)		>.25 ha (20)		
Indigenous (14)				
Other hill people (13)				

Altogether 965 statements from 111 key informants, concerning knowledge of forest products from sal forests and their silvicultural characteristics, were collected during the research. These statements were the core for indigenous knowledge acquisition in this research. Statements were categorised into product and silviculture (Table 7.2), and statements by various socio-economic groups of key informants are presented in Tables 7.3 through 7.5.

Table 7.2: Summary of statements

FUG	Knowledge statement on		
	Product	Silviculture	Total
Basanta-hariyali	260	94	354
Rapti	355	207	562
Sugure	22	27	49
Total	637	328	965

Table 7.3: Statements by ethnic group in each FUG
(Number key informants in parentheses)

Ethnic group	Basanta	Rapti	Sugure	Total
Magar	195 (14)	238 (13)	28 (8)	461 (35)
B/C	75 (14)	173 (11)	11 (6)	295 (31)
Occupational	18 (8)	62 (8)	4 (2)	48 (18)
Indigenous	36 (7)	50 (5)	3 (2)	89 (14)
Hill tribe	30 (8)	39 (4)	3 (1)	72 (13)
Total	354 (51)	562 (41)	49 (19)	965 (111)

Table 7.4: Statements by age and gender of respondents
(Number key informants in parentheses)

Age group→	20-50 years		50 years and over		Total
FUG	Female	Male	Female	Male	Total
Basanta	67 (9)	29 (8)	139 (17)	119 (17)	354 (51)
Rapti	14 (6)	44 (5)	53 (12)	451 (18)	562 (41)
Sugure	1 (1)	6 (2)	8 (5)	34 (11)	49 (19)
Total	82 (16)	79 (15)	200 (34)	604 (46)	965 (111)

Table 7.5: Statements by landholding and living sources of respondents
(Number key informants in parentheses)

FUG	Landless		Land holding <.25 ha		Landholding >.25 ha		Total
	Wage-earning	Farming	Wage-earning	Farming	Wage-earning	Farming	Total
Basanta	27 (12)	1 (1)	184 (19)	29 (8)	0 (0)	113 (11)	354 (51)
Rapti	162 (12)	2 (2)	185 (12)	155 (10)	0 (0)	58 (5)	562 (41)
Sugure	3 (2)	0 (0)	5 (4)	32 (9)	3 (1)	6 (3)	49 (19)
Total	192 (26)	3 (3)	374 (35)	216 (27)	3 (1)	177 (19)	965 (111)

7.2 Knowledge of products from sal forests

Data collected from key informants and verified in triangulation processes include a list of plants, uses, or those reported to be sold in the markets. The details including some historical accounts are given in Appendix VI.

7.2.1 Products in use

Forest products are summarized according to their use into 16 categories, and products from each category are given in Table 7.6. Use category includes the use of the products, preferences, ethnic linkages, and quality. Uses were explained for different ethnic groups, age, sex and economic groups. Quantification of the products from particular forests and some accounts of the local, regional and export markets were also recorded. Reasons for not using some products for specific purposes were also presented. Some details are presented below.

Table 7.6: Products in different use categories

Products	**Products**
Compost	Animal bedding, compost
Fibre	Cloth, rope
Fishing	Bait, equipment, cord, toxin
Fodder	Fodder, goat-fodder, lopping season
Food	Curry, ingredient, liquor, oil, pickle, resin, smoke, snacks
Fuel	Fuel, sparking fuelwood
Implement	Dehusker, handle, hunting tool, musical, plough, furniture, yoke
Market	Export, regional, local (included prices in some items)
Medicinal	Allergy, boil-cure, bug-killer, burn, cough, diarrhea, dysentery, ear, eye, fever, food-poisoning, gastric, jaundice, poisonous, repellent, skin, stomach, tooth-cure, toxic, typhoid, urinary-tract, wound Livestock and miscellaneous
Ornamental	Body, festival, garden
Poisonous	Allergy, sedative, toxin
Processing	Fermentation, pain, processing, warming
Small-wood	Small-wood
Spiritual	Spiritual, religious, witch-diversion
Timber	Timber
Utensil	Chopping-board, broom, glue, soap, plate, pot, stick, thatch, umbrella

Plant parts

Fifteen different plant parts are used, and the numbers of species for each plant part are given in Figure 7.1, and number of uses of different parts is shown in Table 7.7. Leaves are the most used part of the plant, and leaves of 90 out of 191 species are used; leaves are used for 102 products.

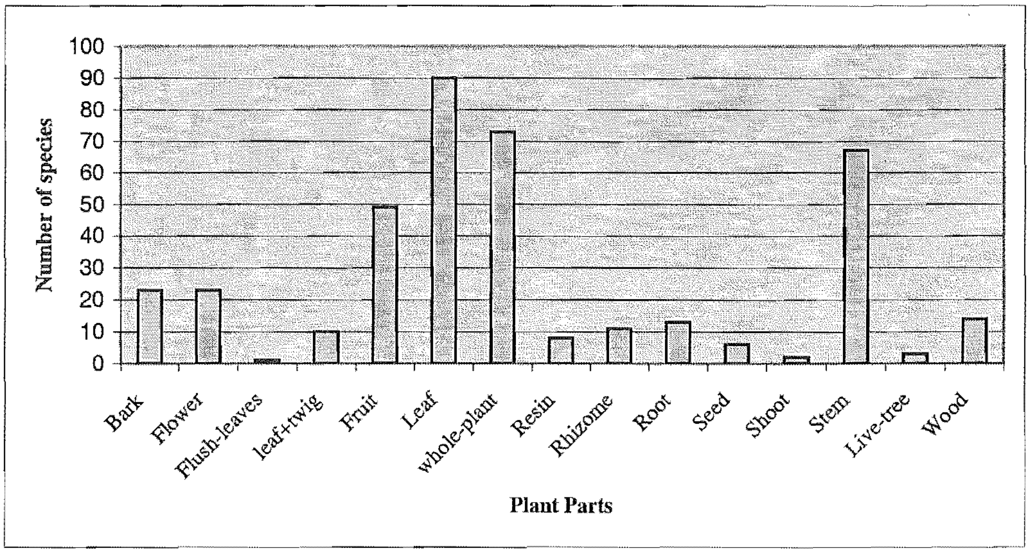

Figure 7.1: Number of species for each plant product

Table 7.7: Use of different plant parts

Products	Number of species: Bark	Branch	Flower	Flush leaves	Fruit	Leaf	Plant	Resin	Rhi-zome	Root	Seed	Shoot	Stem	Live Tree	TOTAl
Compost						5	2								7
Fibre	4				1	1	1						5		12
Fishing	2				4		1				1		1		9
Fodder					1	74	54				1		1		131
Food			10		29	12	5	1	5	1	1	1	1		66
Fuel		12								1	16				29
Implement	1									1			17		18
Market	5		1		9	1	4		2	1	1				24
Medicinal	13	2	3		21	12	19	5	5	9	1	1	7		98
Ornamental			8					1					3		12
Poisonous				1	3			1			1				6
Processing	3		3			1			2				1		10
Small-wood													14		14
Spiritual			1		2	1	1			1				3	9
Timber													24		24
Utensil	1				1	7	11	1					4		25
	29	14	26	1	71	114	98	9	14	14	22	2	78	3	495

7.2.2 Species in use

Users from all three users groups are known to use 191 species for 16 different uses as detailed in Appendix VI. Number of species for each use is presented in Figure 7.2.

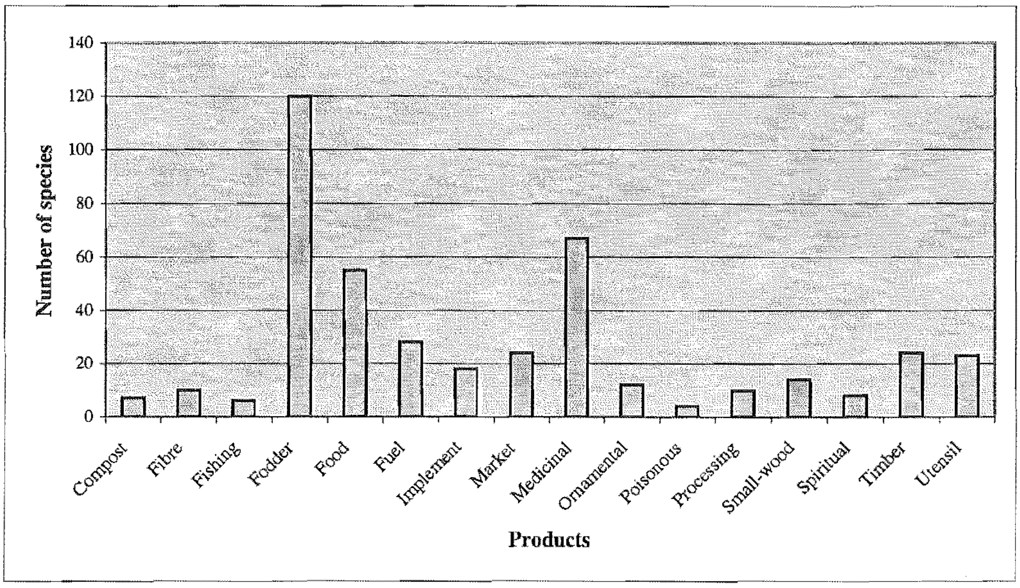

Figure 7.2: Species for different product from sal forests

Plants of different life forms are used (Table 7.8). Depending upon the species, trees are used for all purposes followed by shrubs and lianas, which are used for 12 out of the 16 possible products/uses. Herbs and grasses are used for 11 and 9 products, respectively. Similarly ferns, palms and fungi are used for four, three and two products, respectively.

These details underscore the large spectrum of resources in sal forests, and almost all species have been known to be of some benefit to forest users. Many of the species are producing more than one product, and harvesting some of these products does not involve felling the tree.

Many products are identified as saleable in the markets on a scale from 'local' to 'exporting to India'. Thus for some users, sal forests, besides meeting subsistence needs, are generating income.

Table 7.8: Species in use by life form

Products	Life form								Total
	Fern	Fungi	Grass	Herb	Liana	Palm	Shrub	Tree	
Compost			1	1	1		2	2	7
Fibre			1	3	2		1	3	10
Fishing					1			5	6
Fodder	2		18	20	21		11	48	120
Food		1	1	9	7	1	9	27	55
Fuel				2	1		2	23	28
Implement				1			1	16	18
Market		1	1	4	3	1	1	13	24
Medicinal	2		2	17	13		5	28	67
Ornamental			1	1	1		3	6	12
Poison					1			3	4
Processing			1	5			1	3	10
Small-wood								14	14
Spiritual	1				1		2	4	8
Timber							1	23	24
Utensil	1		8	2	4	2		6	23
# Uses	4	2	9	11	12	3	12	16	16

7.3 Silvicultural knowledge

Forest users were found to be not only familiar with the uses but also aware of the silivicultural characteristics of many species (Appendix VII). Silvicultural knowledge derived from the users is grouped into eight categories (Table 7.9), and these are categorized according to life forms (Table 7.10).

Table 7.9: Categories of ethnosilvicultural knowledge

(Figure in parentheses denote the # of species)

Silvicultural aspects	**Components**	**# species**
Abundance	Decreasing (2), few (5), increasing (4), many (8), rare (5)	23
Associate	Complementary (18), deleterious (4) indicator (3)	25
Dispersal	Bear (3), bird (9), explosive (2), deer (1), local (1), porcupine (1), wild-chicken (3), wind (3)	17
Distribution	Confined (1), highland (12), lowland (2)	14
Phenology	Flowering (31), fruiting (11), growth (2), life-cycle (14), lopping season (1), ripening (10), seeding (1) shedding (10), sprouting (3)	52
Propagation	Adverse factor (1), bird-dropping (1), rhizome (2), root (5), seed (8)	13
Site	Sun (3), broad (2), cliff (1), colonizer (2), depression (3), dry (8), farm-fringe (1), fertile (1), flat (5), highland (1), lowland (1), moist (13), riverside (4), shade (9), slope (3)	47
General feature	Flower (8), fruit (16), growth (2), leaf (3), seed (6), stem (1), tree-size (17), variety (5)	39
Total		97

Table 7.10: Ethnosilvicultural knowledge by life form (# species)

Silvicultural aspects	Life form								
	Fern	Fungi	Grass	Herb	Liana	Palm	Shrub	Tree	Total
Abundance			2	2	3		1	15	23
Associate			1	2	8		1	13	25
Dispersal				1	3	1	2	10	17
Distribution					3		1	10	14
Phenology		1	1	7	12	1	5	25	52
Propagation				1	4		1	7	13
Site	2		5	10	8		3	19	47
General feature	1			5	6	1	4	22	39

7.4 Relationship between indigenous knowledge and respondent

The indigenous knowledge was categorized into product and ethnosilviculture, and respondents into categories of gender, age, ethnicity, main-income group, and landholding classes. The relationships between indigenous knowledge and respondents were analyzed for Basanta and Rapti forests, by chi-square test of association (Cramer, 1998; SPSS, 1999).

7.4.1 Gender

Different knowledge categories by gender of respondents are presented in Tables 7.11 through 7.15. Both women and men mentioned all life forms in their statements in Basanta, whereas women of Rapti did not indicate fern, fungi and grass (Table 7.11). In the case of knowledge of uses of plant parts, women showed more knowledge (seed was not mentioned by men) than men in Basanta, but women of Rapti did not mention foliage, whole plant, seed, tree and wood which were mentioned by men (Table 7.12).

Table 7.11: Knowledge of different life form by gender in both forests

Life forms	Basanta			Rapti		
	Female	Male	Total	Female	Male	Total
Fern	2	3	5		7	7
Fungi	2	1	3		1	1
Grass	15	8	23		26	26
Herb	25	18	43	3	68	71
Liana	37	13	50	20	82	102
Palm				2	15	17
Shrub	22	13	35	4	51	55
Tree	103	92	195	38	245	283
Total	206	148	354	67	495	562

Table 7.12: Knowledge of different plant parts by gender in both forests

Plant parts	Basanta			Rapti		
	Female	Male	Total	Female	Male	Total
Bark	6	5	11	1	21	22
Flower	9	5	14	1	16	17
Foliage	8	1	9		6	6
Fruit	19	14	33	3	66	69
Leaf	44	16	60	15	62	77
Plant	38	14	52		60	60
Resin	2	3	5	1	5	6
Rhizome	6	1	7	1	9	10
Root	2	3	5	1	10	11
Seed	2		2		7	7
Shoot					1	1
Stem	28	32	60	10	43	53
Tree	1	1	2		1	1
Wood					15	15
Total	165	95	260	33	322	355

In Basanta, women and men were familiar with the same types of products from sal forests, whereas a different status of knowledge was shown at Rapti (Table 7.13). Women did not list the products for fishing, fuelwood, ornamental, poisonous, processing and spiritual plant products that were known to men.

Table 7.13: Knowledge of different uses of sal forest by gender

Products	Basanta			Rapti		
	Female	Male	Total	Female	Male	Total
Compost	6	3	9			
Fibre	6	2	8	2	5	7
Fishing	1	1	2		7	7
Fodder	64	17	81	5	69	74
Food	19	10	29	7	64	71
Fuel	11	5	16		13	13
Implement	3	4	7	5	14	19
Market	8	8	16	1	22	23
Medicinal	22	15	37	8	71	79
Ornamental	5	3	8		4	4
Poisonous					4	4
Processing	3	2	5		7	7
Small-wood	6	5	11	1	7	8
Spiritual	2	2	4		5	5
Timber	1	16	17	3	11	14
Utensil	8	2	10	1	19	20
Total	165	95	260	33	322	355

Men in Basanta showed their knowledge in seed dispersal, which was not recorded by women (Table 7.14). In Rapti women did not mention knowledge of associate species, distribution of species or propagation, which were indicated by men.

Table 7.14: Knowledge of silviculture by gender

Silvicultural	Basanta			Rapti		
aspects	Female	Male	Total	Female	Male	Total
Abundance	7	4	11	1	11	12
Associate	12	4	16		11	11
Dispersion		5	5	5	9	14
Distribution	7	1	8		7	7
Phenology	1	13	14	12	57	69
Propagation	1	3	4		13	13
Site	11	8	19	3	35	38
Taxonomy	2	15	17	13	30	43
Total	41	53	94	34	173	207

Number of statements for each knowledge group by gender for both forests are summarised in Table 7.15.

Table 7.15: Number of knowledge statements by gender in two forests

(Numbers in parentheses are percentage of male or female)

	Basanta			Rapti			Total		
Gender	Female	Male	Total	Female	Male	Total	Female	Male	Total
Silvics	41 (44)	53 (56)	94 (100)	34 (16)	173 (84)	207 (100)	75 (25)	226 (75)	301 (100)
Uses	165 (63)	95 (37)	260 (100)	33 (9)	322 (91)	355 (100)	198 (32)	417 (68)	615 (100)
Total	206 (58)	148 (42)	354 (100)	67 (12)	495 (88)	562 (100)	273 (30)	643 (70)	916 (100)

The association of two categories of information (use and silvics of species) and gender is significant (χ^2=5.11, p=0.024) in combined analysis. Males have a higher number of statements than females in both knowledge categories. However, males showed more knowledge (75%) in silvics than in uses (68%); females showed more on uses (32%) than in silvics (25%).

The association is significant in both forest users groups (χ^2=11.17, p =0.001 for Basanta and χ^2=6.33, p=0.012 for Rapti). In Basanta, males possessed more knowledge of silviculture but females demonstrated more of uses. In Rapti, females showed more knowledge of silvics than of uses, and the males' knowledge was more of uses.

Two forests gave contrasting results on knowledge status between females and males. Knowledge of forest products from sal forests varied between the two forests. Female-users of Basanta had higher knowledge of fodder and medicine, whereas male-users' knowledge was more on timber. Knowledge of other products was shown by both sexes. Older women have more knowledge of fodder than younger, but information on medicine is from both age groups. In Rapti, males have demonstrated more knowledge in all products; older men have more knowledge than younger men (69 vs 26).

Men's statements on silvics are higher in both forests, and the association of gender with silvicultural knowledge was highly significant in Basanta. Males have shown more knowledge of general features and phenology in Basanta, whereas females know more on associated species. Other aspects of silviculture are mentioned by both men and women in Basanta. In Rapti, females did not mention anything about associated species, distribution or propagation (Table 7.14).

7.4.2 Age

Indigenous knowledge of forest products and silviculture by age group are presented in Tables 7.16 through 7.20. Although both groups demonstrated knowledge in all life forms (Table 7.16) and plant parts (Table 7.17), older people (over 50 years of age) demonstrated more knowledge than younger people in most cases in both forests. Only in a few cases (fungi life form in Rapti, and products from bark, foliage and root in Basanta), the younger group showed more statements than the older.

Table 7.16: Knowledge of different life form by age

Life forms	Basanta			Rapti		
	20-50 years	> 50 years	Total	20-50 year	> 50 years	Total
Fern	2	3	5	2	5	7
Fungi		3	3	1		1
Grass	7	16	23	4	22	26
Herb	9	34	43	5	66	71
Liana	12	38	50	7	95	102
Palm				4	13	17
Shrub	8	27	35	4	51	55
Tree	58	137	195	31	252	283
Total	96	258	354	58	504	562

Table 7.17: Knowledge of different plant parts by age

Plant parts	Basanta			Rapti		
	20-50 years	> 50 years	Total	20-50 years	> 50 years	Total
Bark	6	5	11		22	22
Flower	3	11	14		17	17
Foliage	5	4	9		6	6
Fruit	11	22	33	8	61	69
Leaf	12	48	60	11	66	77
Plant	16	36	52	7	53	60
Resin	1	4	5		6	6
Rhizome	2	5	7	1	9	10
Root	4	1	5		11	11
Seed		2	2	1	6	7
Shoot					1	1
Stem	18	42	60	7	46	53
Tree	1	1	2		1	1
Wood				1	14	15
Total	79	181	260	36	319	355

Both age groups showed knowledge of all products, except for poisonous ones, in Basanta, though the older age group indicated a greater number of statements (Table 7.18). In Rapti, too, the older age group demonstrated a greater knowledge of all products, but the younger group did not show any knowledge on fishing, ornamental, poisonous, processing, spiritual or timber products (Table 7.18).

In silvicultural knowledge, the older group showed more knowledge in both forests (Table 7.19). The younger group mentioned only about abundance, associate species, site and general features in Basanta, and in all aspects except seed dispersal and propagation in Rapti.

Table 7.18: Knowledge of different uses of sal forest by age

Products	Basanta			Rapti		
	20-50 years	> 50 years	Total	20-50 years	> 50 years	Total
Compost	3	6	9			
Fibre	2	6	8	2	5	7
Fishing	1	1	2		7	7
Fodder	21	60	81	7	67	74
Food	7	22	29	3	68	71
Fuel	4	12	16	1	12	13
Implement	3	4	7	5	14	19
Market	1	15	16	7	16	23
Medicinal	15	22	37	7	72	79
Ornamental	2	6	8		4	4
Poisonous					4	4
Processing	2	3	5		7	7
Small-wood	4	7	11	1	7	8
Spiritual	3	1	4		5	5
Timber	7	10	17		14	14
Utensil	4	6	10	3	17	20
Total	79	181	260	36	319	355

Table 7.19: Knowledge of silviculture of sal forest by age

Silvicultural	Basanta			Rapti		
aspects	20-50 years	> 50 years	Total	20-50 years	> 50 years	Total
Abundance	4	7	11	2	10	12
Associate	6	10	16	1	10	11
Dispersion		5	5		14	14
Distribution		8	8	2	5	7
Phenology		14	14	7	62	69
Propagation		4	4		13	13
Site	6	13	19	3	35	38
Taxonomy	1	16	17	7	36	43
Total	17	77	94	22	185	207

Summary of knowledge categories by age classes for both forests and combined are presented in Table 7.20.

Table 7.20: Summary of knowledge by age in two forests

(Numbers in parentheses are percentage of two age groups)

	Basanta			Rapti			Combined		
Age	< 50 year	> 50 years	Total	< 50 years	> 50 year	Total	< 50 years	> 50 year	Total
Silvic	17 (18)	77 (82)	94 (100)	22 (11)	185 (89)	207 (100)	39 (13)	262 (87)	301 (100)
Use	79 (30)	181 (70)	260 (100)	36 (10)	319 (90)	355 (100)	115 (19)	500 (81)	615 (100)
Total	96 (27)	258 (73)	354 (100)	58 (10)	504 (90)	562 (100)	154 (17)	762 (83)	916 (100)

Knowledge and age groups showed a significant association in combined analysis (χ^2=4.765, p=0.029) and in Basanta forest users groups (χ^2=5.284, p =0.022), but this was not significant in Rapti (χ^2=0.034, p=0.855). Respondents with an age above 50 years indicated greater knowledge on silviculture.

In all three instances (i.e., Basanta, Rapti and combined), older people demonstrated more knowledge in both categories. The analysis showed that older people have significantly more knowledge of silviculture than of forest uses. Younger people have more knowledge of uses than of silviculture.

7.4.3 Ethnic group

Indigenous knowledge statuses by ethnic groups are presented in Tables 7.21 through 7.25. Magar showed knowledge of all the life form in Basanta forest followed by B/C which showed knowledge in all life forms except fungi (Table 7.21). Other ethnic groups have shown knowledge of most of the life forms except fern and fungi; the occupational group did not show a knowledge in fern, fungi or grass. In the case of Magar and B/C in Rapti, the data showed the opposite of Basanta; some groups did not indicate their knowledge of fern, fungi, grass and/or palm (Table 7.21). Similar results are shown in different ethnic groups' knowledge of different plant parts in both forests; Magar, B/C and indigenous groups have shown knowledge of a larger number of plant parts than have other groups (Table 7.22)

Table 7.21: Knowledge of different life form by ethnic group

Life forms	Basanta						Rapti					
	Magar	B/C	Occupational	Indigenous	Other	Total	Magar	B/C	Occupational	Indigenous	Other	Total
Fern	2	2		1		5	5	2				7
Fungi	3					3		1				1
Grass	7	9		4	3	23	11	10	4	1		26
Herb	33	2	2	4	2	43	30	21	7	8	5	71
Liana	22	14	2	5	7	50	48	29	11	7	7	102
Palm							7	7		2	1	17
Shrub	18	9	1	3	4	35	22	17	8	5	3	55
Tree	110	39	13	19	14	195	115	86	32	27	23	283
Total	195	75	18	36	30	354	238	173	62	50	39	562

Table 7.22: Knowledge of different plant parts by ethnic group

Plant parts	Basanta						Rapti					
	Magar	B/C	Occupational	Indigenous	Other	Total	Magar	B/C	Occupational	Indigenous	Other	Total
Bark	3	4		3	1	11	7	5	5	2	3	22
Flower	10	3		1		14	8	5	1	3		17
Foliage	5	4				9	2	2		2		6
Fruit	17	8	2	4	2	33	23	26	9	6	5	69
Leaf	31	11	4	6	8	60	28	35	6	4	4	77
Plant	24	10	4	8	6	52	20	23	5	7	5	60
Resin	5					5	2	3		1		6
Rhizome	5			2		7	6	1	2		1	10
Root	1	2	1	1		5	4	7				11
Seed					2	2	3	3	1			7
Shoot							1					1
Stem	33	15	3	6	3	60	22	18	5	6	2	53
Tree		1		1		2		1				1
Wood							11	1			3	15
Total	134	58	14	32	22	260	137	130	34	31	23	355

Aspects of knowledge of forest use by ethnic group are presented in Table 7.23 for both forests. Magar, B/C and indigenous groups in Basanta showed most knowledge covering most of the aspects although Magar scored the highest followed by B/C. Magar and B/C groups in Rapti showed more knowledge than other groups. However, all the ethinic groups indicated some sort of knowledge of forest products in both forests.

Table 7.23: Knowledge of different uses of sal forests by ethnic group

Products	Basanta						Rapti					
	Magar	B/C	Occupational	Indigenous	Other	Total	Magar	B/C	Occupational	Indigenous	Other	Total
Compost	4	3		1	1	9						
Fibre	3	2		1	2	8	4	3				7
Fishing	1			1		2	2	3		1	1	7
Fodder	38	15	8	9	11	81	23	38	2	9	2	74
Food	20	3	1	3	2	29	33	27	5	4	2	71
Fuel	12	2	1	1		16	11	2				13
Implement	4	2		1		7	8	7	1	3		19
Market	9	2	1	1	3	16	2	11	2	3	5	23
Medicinal	18	14		4	1	37	29	23	15	4	8	79
Ornamental	6	2				8	3	1				4
Poisonous								4				4
Processing	3	1		1		5	4	2		1		7
Small-wood	6	2	1	1	1	11	5	3				8
Spiritual		2		2		4	3	1	1			5
Timber	6	5	2	3	1	17	3	3	3	3	2	14
Utensil	4	3		3		10	7	2	5	3	3	20
Total	134	58	14	32	22	260	137	130	34	31	23	355

Out of the 94 elements (one statement is one element) of silviculture in Basanta 65% was from Magar, and 18% from B/C (Table 7.24). Seventeen percent of the silvicultal elements were from other ethinic groups. Magar and B/C covered all (except one, i.e., B/C did not cover distribution) aspects of silviculture in Basanta. In Rapti, Magar, B/C and indigenous groups covered all aspects and others, too, have demonstrated in most of the aspects (Table 7.24).

Table 7.24: Knowledge of silviculture of sal forests

Silvicultural aspects	Basanta						Rapti					
	Magar	B/C	Occupational	Indigenous	Other	Total	Magar	B/C	Occupational	Indigenous	Other	Total
Abundance	8	1	1	1		11	9	1		2		12
Associate	10	2	2	2		16	5	4		2		11
Dispersion	2	2	1			5	4	4	3	3		14
Distribution	8					8	4	2		1		7
Phenology	9	3			2	14	27	14	16	3	9	69
Propagation	3	1				4	7	1	2	2	1	13
Site	12	4			3	19	22	8	5	2	1	38
Taxonomy	9	4		1	3	17	23	9	2	4	5	43
Total	61	17	4	4	8	94	101	43	28	19	16	207

Knowledge status among the ethnic groups is summarised in Table 7.25, for both forests, separately and combined.

Table 7.25: Knowledge by ethnic group

(Numbers in parentheses denote percentage of ethnic groups)

Ethnic group	Basanta			Rapti			Combined		
	Silvic	Use	Total	Silvic	Use	Total	Silvic	Use	Total
Magar	61(65)	134 (52)	195 (55)	101 (49)	137 (39)	238 (42)	162 (54)	271 (44)	433 (47)
B/C	17 (18)	58 (22)	75 (21)	43(21)	130 (37)	173 (31)	60 (20)	188 (31)	248 (27)
Occupational	4 (4)	14 (5)	18 (5)	28 (13)	34 (9)	62 (11)	32 (10)	48 (8)	80 (9)
Indigenous	4 (4)	32 (12)	36 (10)	19 (9)	31 (9)	50 (9)	23 (8)	63 (10)	86 (9)
Other	8 (9)	22 (9)	30 (9)	16 (8)	23 (6)	39 (7)	24 (8)	45 (7)	69 (8)
Total	94 (100)	260 (100)	354 (100)	207 (100)	355 (100)	562 (100)	301 (100)	615 (100)	916 (100)

Knowledge group and ethnic group showed a significant association overall (χ^2=15.934, p=0.003) and in Rapti forest users groups (χ^2 = 16.052, p =0.003), but was not significant in Basanta (χ^2 =7.392, p=0.117). Magar, occupational group and other hill-people groups showed more knowledge of silviculture than of forest products in Rapti and combined, whereas B/C and indigenous groups showed more knowledge of forest products than silviculture.

7.4.4 Income group

The wage-earning group showed more knowledge of all life forms in both forests, although both income groups have indicated their knowledge of all life forms, except fern by the farming group in Basanta and fungi bythe farming group in Rapti (Table 7.26). Similar results are shown relating to knowledge of product from different plant parts (Table 7.27).

Table 7.26: Knowledge of different life form by income group

Life forms	Basanta			Rapti		
	Wage-earning	Farming	Total	Wage-earning	Farming	Total
Fern	5		5	4	3	7
Fungi	2	1	3	1		1
Grass	14	9	23	18	8	26
Herb	30	13	43	41	30	71
Liana	30	20	50	62	40	102
Palm				11	6	17
Shrub	21	14	35	34	21	55
Tree	109	86	195	176	107	283
Grand Total	211	143	354	347	215	562

Table 7.27: Knowledge of different plant parts by income group

Plant parts	Basanta			Rapti		
	Wage-earning	Farming	Total	Wage-earning	Farming	Total
Bark	5	6	11	15	7	22
Flower	8	6	14	7	10	17
Foliage	9		9	5	1	6
Fruit	18	15	33	36	33	69
Leaf	27	33	60	52	25	77
Plant	36	16	52	35	25	60
Resin	2	3	5	2	4	6
Rhizome	3	4	7	4	6	10
Root	3	2	5	4	7	11
Seed		2	2	3	4	7
Shoot					1	1
Stem	39	21	60	29	24	53
Tree		2	2		1	1
Wood				9	6	15
Total	150	110	260	201	154	355

Both income groups in Basanta indicated knowledge of all uses from sal forests, and the results were not much different in Rapti (Table 7.28). In both forests, wage-earning groups demonstrated more knowledge than the farming group.

Table 7.28: Knowledge of different uses from sal forests by income group

Products	Basanta			Rapti		
	Wage-earning	Farming	Total	Wage-earning	Farming	Total
Compost	7	2	9			
Fibre	7	1	8	7		7
Fishing	1	1	2	5	2	7
Fodder	41	40	81	44	30	74
Food	15	14	29	34	37	71
Fuel	12	4	16	7	6	13
Implement	4	3	7	13	6	19
Market	8	8	16	15	8	23
Medicinal	24	13	37	43	36	79
Ornamental	4	4	8	2	2	4
Poisonous				1	3	4
Processing	4	1	5	5	2	7
Small-wood	5	6	11		8	8
Spiritual	1	3	4	1	4	5
Timber	10	7	17	9	5	14
Utensil	7	3	10	15	5	20
	150	110	260	201	154	355

Both groups in both forests showed knowledge of all aspects of silviculture, except propagation by the farming group in Basanta (Tabale 7.29). Wage-earning groups showed more knowledge of ethnosilviculture than the farming group.

Table 7.29: Knowledge of ethnosilviculture of sal forests by income group

Silvicultural aspects	Basanta			Rapti		
	Wage-earning	Farming	Total	Wage-earning	Farming	Total
Abundance	9	2	11	6	6	12
Associate	9	7	16	8	3	11
Dispersion	4	1	5	12	2	14
Distribution	5	3	8	6	1	7
Phenology	8	6	14	48	21	69
Propagation	4		4	12	1	13
Site	13	6	19	28	10	38
Taxonomy	9	8	17	26	17	43
	61	33	94	146	61	207

Knowledge demonstrated by different income groups in both forests, separately and combined are presented in Table 7.30.

Table 7.30: Knowledge by income group in two forests

Category	Basanta			Rapti			Combined		
	Wage-earning	Farming	Total	Wage-earning	Farming	Total	Wage-earning	Farming	Total
Silvic	61 (65)	33 (35)	94(100)	146 (71)	61 (29)	207 (100)	207 (69)	94 (31)	301 (100)
Use	150 (58)	110 (42)	260 (100)	201 (57)	154 (43)	355 (100)	351 (57)	264 (43)	615 (100)
Total	211 (60)	143 (40)	354 (100)	347 (62)	215 (38)	562 (100)	558 (61)	358 (39)	916 (100)

The association of two categories of information (use and silviculture of species) and income groups was significant in the overall analysis (χ^2=11.615, p=0.001), and in Rapti forest users groups (χ^2=10.713, p=0.001), but it was not significant in Basanta (χ^2=1.487, p=0.223). Wage-earning respondents had more knowledge of silviculture, and farming respondents had more knowledge of products.

7.4.5 Landholding groups

Tables 7.31 through 7.35 show the indigenous knowledge status among different groups in both the forests of this present study. The small landholding (<.025 ha) group showed knowledge of all life forms and plant parts in both forests, followed by large landholders (>0.25 ha) in Basanta and the landless in Rapti (Tables 7.31 and 7.32).

Table 7.31: Knowledge of different life form by landholding group

Life forms	Basanta				Rapti			
	Landless	< 0.25 ha	> 0.25 ha	Total	Landless	< 0.25 ha	> 0.25 ha	Total
Fern	1	4		5	1	6		7
Fungi		2	1	3		1		1
Grass		14	9	23	8	15	3	26
Herb	4	28	11	43	22	43	6	71
Liana	4	30	16	50	25	63	14	102
Palm					2	11	4	17
Shrub	2	26	7	35	19	27	9	55
Tree	17	109	69	195	87	174	22	283
Total	28	213	113	354	164	340	58	562

Table 7.32: Knowledge of different plant parts by landholding group

Plant parts	Basanta				Rapti			
	Landless	< 0.25 ha	> 0.25 ha	Total	Landless	< 0.25 ha	> 0.25 ha	Total
Bark		6	5	11	9	12	1	22
Flower	1	7	6	14	3	9	5	17
Foliage	3	6		9	2	4		6
Fruit	1	19	13	33	20	49		69
Leaf	3	31	26	60	19	48	10	77
Plant	3	34	15	52	15	37	8	60
Resin	1	1	3	5		6		6
Rhizome		4	3	7	3	4	3	10
Root		4	1	5		10	1	11
Seed		2		2	1	6		7
Shoot						1		1
Stem	1	39	20	60	9	41	3	53
Tree		1	1	2		1		1
Wood					4	6	5	15
Total	13	154	93	260	85	234	36	355

Small landholding (<0.25 ha) groups demonstrated knowledge of all products and ethnosilviculture of sal forests in both sites, followed by large landholders in Basanta and landless in Rapti (Tables 7.33 and 7.34). The landless group in Rapti showed knowledge in all aspects of silviculture.

Table 7.33: Knowledge of different uses of sal forests by landholding group

Products	Basanta				Rapti			
	Landless	< 0.25 ha	> 0.25 ha	Total	Landless	< 0.25 ha	> 0.25 ha	Total
Compost	4	3	2	9				
Fibre		7	1	8		7		7
Fishing		2		2	3	4		7
Fodder	3	45	33	81	10	49	15	74
Food	2	15	12	29	17	46	8	71
Fuel	1	11	4	16	1	7	5	13
Implement		4	3	7	2	15	2	19
Market		10	6	16	7	16		23
Medicinal	2	25	10	37	28	49	2	79
Ornamental	1	3	4	8		2	2	4
Poisonous						4		4
Processing		4	1	5	1	5	1	7
Small-wood		5	6	11		8		8
Spiritual		2	2	4	1	4		5
Timber		11	6	17	6	8		14
Utensil		7	3	10	9	10	1	20
Total	13	154	93	260	85	234	36	355

Table 7.34: Knowledge of ethnosilviculture of sal forests by landholding group

Silvicultural aspects	Basanta				Rapti			
	Landless	< 0.25 ha	> 0.25 ha	Total	Landless	< 0.25 ha	> 0.25 ha	Total
Abundance	5	5	1	11	3	6	3	12
Associate	1	8	7	16	5	4	2	11
Dispersion	2	3		5	11	2	1	14
Distribution		5	3	8	2	4	1	7
Phenology	4	8	2	14	32	32	5	69
Propagation		4		4	4	8	1	13
Site	1	12	6	19	10	24	4	38
Taxonomy	2	14	1	17	12	26	5	43
	15	59	20	94	79	106	22	207

Indigenous knowledge of forest products from and silviculture of sal forests among different landholding groups are presented in Table 7.35.

Table 7.35: Knowledge by landholding group in two forests
(Numbers in parentheses are percentages of different land classes)

Category	Basanta				Rapti				Combined			
	Landless	<0.25 ha	>0.25 ha	Total	Landless	<0.25 ha	>0.25 ha	Total	Landless	<0.25 ha	>0.25 ha	Total
Silvic	15 (16)	59 (63)	20 (21)	94(100)	79 (38)	106 (51)	22 (11)	207 (100)	94 (31)	165 (55)	42 (14)	301 (100)
Use	13 (5)	154 (59)	93 (36)	260 (100)	85 (24)	234 (66)	36 (10)	355 (100)	98 (16)	388 (63)	129 (21)	615 (100)
Total	28 (8)	213 (60)	113 (32)	354 (100)	164 (29)	340 (61)	58 (10)	562 (100)	192 (21)	553 (60)	171 (19)	916 (100)

Landholding groups have a highly significant association with the knowledge group in combined (χ^2=30.181, p=0.000), and separate analysis for both forest users groups (χ^2=15.166, p=0.001 for Basanta and χ^2=13.767, p=0.001 for Rapti). Overall, the landless group had more information on silviculture, whereas other landholding groups had more knowledge of products. In Basanta-hariyali, the landless and small-landholding groups had significantly more knowledge of silviculture whereas large-landholders had more knowledge of products. In Rapti too, the landless group had more knowledge of silviculture, but other landholding groups had more of products.

7.5 Synopsis of the results

The respondent's statements and the subsequent analysis explored local knowledge of multiple products and ethnosilviculture. Knowledge is differentially distributed among forest users according to gender, age, ethnic/caste group, income-earning group and landholding group in the two sites.

In summary, the following are statements specific to socio-economic groups among users, relating to the indigenous knowledge of multiple products and the ethnosilviculture of sal forest, based on the results from the present study. Chi-square test results are summarised in Table 7.36.

Gender and indigenous knowledge:

- Both sexes demonstrated knowledge of all life forms in Basanta, but the number of statements were higher from women i.e., 58% women versus 42% men.
- Women did not show their knowledge of all the life forms that were included in the men's knowledge in Rapti, and the number of women's statements were far fewer compared to men's, i.e., 12% women versus 88% men.
- Women indicated more knowledge of products from different plant parts in Basanta, i.e., 63% products versus 37% silviculture.

- Women showed less knowledge of products than men in Rapti, i.e., 9% women versus 91% men.

- Women showed less knowledge of silviculture than men in both forests, i.e. 44% women versus 56% men in Basanta, and 16% women versus 84% men in Rapti.

Age and indigenous knowledge

- Older people showed knowledge of all life forms in Basanta, but the younger group lacked knowledge of fungi. Based upon the number of statements, older people rated far higher compared to younger people, i.e. 73% older versus 27% younger.

- In Rapti the younger showed knowledge of all life forms, but the older group did not show any knowledge of fungi. However, the total number of statements were more for the older group, i.e., 90% older versus 10% younger.

- Both age groups demonstrated knowledge of plant parts in use (except seed which was not indicated by the younger group) and all uses in Basanta. The older group held more knowledge than the younger, 70% older versus 30% younger.

- In Rapti, the younger group indicated less knowledge of the plant parts and their use, i.e. 90 % for older and 10% for younger group.

- Silvicultural knowledge was found much less in the younger group compared to the older group in both forests, i.e., 18% younger versus 82% older in Basanta, and 11% younger versus 89% older in Rapti.

Ethnic group and indigenous knowledge

- Magar showed knowledge of all life forms in Basanta, followed by B/C. The total knowledge statements of life forms in Basanta constituted 55%, 21%, 10%, 9% and 5% for Magar, B/C, indigenous, other-hill-people and occupational groups, respectively.

- B/C showed knowledge of all life forms in Rapti, and Magar showed it in all except fungi. Proportions of statement were 42%, 31% and 11% respectively for Magar, B/C, and occupational, respectively. Indigenous and other-hill-people groups constituted 9% and 7%, respectively.

- Magar and B/C showed more knowledge of plant-parts and their use in both forests. However, other groups have also indicated knowledge of uses from sal forest. Similar results are recorded in silvicultural knowledge.

Income and indigenous knowledge

- The wage-earning group revealed more knowledge in all knowledge categories in both forests compared to farming group. Wage-earners' knowledge ranged from 58% in usage to 65% in silviculture in Basanta, and from 57% in usage to 70% in silviculture in Rapti.

Landholding and indigenous knowledge

- The small-landholding group demonstrated more knowledge among landholding groups in all categories in both forests, followed by large-landholding group in Basanta and landless group in Rapti.

Table 7.36: Summary table from chi-square test of independence

Respondent group	Level	Higher knowledge by group of		Significance level[1]
		Products	Silviculture	
Gender	Combined	Female	Male	*
	Basanta	Female	Male	**
	Rapti	Male	Female	*
Age	Combined	20-50 years	Over 50 years	*
	Basanta	20-50 years	Over 50 years	*
	Rapti	Over 50 years	20-50 years	NS
Ethnic group	Combined	B/C and indigenous	Magar & occupational	**
	Basanta	B/C and occupational	Magar and indigenous	NS
	Rapti	B/C and hill	Magar and occupational	**
Income source group	Combined	Farming	Wage-earning	**
	Basanta	Farming	Wage-earning	NS
	Rapti	Farming	Wage-earning	**
Landholding	Combined	Small and large	Landless	***
	Basanta	Large	Landless and small	**
	Rapti	Small	Landless and large	**

[1]- *, ** and *** denote significant at .05, .01, and .001 levels respectively, and NS denotes not significant at .05.

CHAPTER VIII. DISCUSSION

Discussions in this chapter are centred on the following hypotheses, as set out in 1.4, and in reference to the research results, i.e., results after one year following one-event lopping:

- Lopping and litter removal do not significantly affect stem growth (Chapter V);
- Lopping and litter removal do not significantly affect forest regeneration (Chapter VI);
- Local people have indigenous knowledge of multiple products from sal forests (Chapter VII); and
- The poor of the community hold a larger portion of ethnosilvicultural knowledge than the wealthy (Chapter VII).

Although this study became part of the operational plan implementation of two community forests, the discussion here was based only on growth of one year after treatment. Experimental plots were established with the intention of identifying the level of lopping and litter removal that would produce foliage for local users while having minimal impact on tree growth. The study involved the analysis of growth (dbh, height, basal area and volume at both tree and plot level) and changes in regeneration as responses to different lopping and litter removal intensities. Although lopping effects have been elsewhere assessed on the changes in stem tapering, , stem shape and dominance, these measures were not within the scope of this research.

Investigation on effects of one-event lopping and litter removal on tree growth were studied in two forests. The results are relevant to natural young sal forests with stocking between 15000 and 28000 ha-1. However, it has to be noted that one-event lopping may be a poor predictor of response to multiple loping treatments as illustrated by the differences reported earlier section between one-off and repeated lopping (Chapter Two).

Treatment effects on regeneration were assessed on the basis of changes in numbers of plants/ramets during the experimental period. The study did not make any investigation of the survival of plants/ramets that were recorded in the first census. Further study will be required to investigate the survival of regenerated seedlings.

8.1 The experimental forests

Two separate sal forests, Basanta and Rapti, located in higher-slopes and lower-plains respectively, made an elevational continuum from 200 m to 1000 m. Both forests are part of large forest blocks, extending several hills, slopes and valleys. The forests are within the natural zone of sal forests (FAO, 1985; Jackson, 1994; Tewari, 1995).

Species composition varied between the forests (62 families and 141 species in Basanta, and 60 families and 128 species in Rapti identified; 48 and 33 species unidentified in Basanta and Rapti, respectively), but many are common to both forests (39 families and 67 species identified, and 31 species unidentified). Species composition is not different from other studies (Alam, 1996; Aryal *et al.*, 1999). Alam (1996) recorded 160 woody genera comprising 56 families in a sal forest.

Stocking varied from 14775-16300 stems ha^{-1} (Table 4.4 for Basanta) to 27525-28800 stems ha^{-1} (Table 4.9 for Rapti). At the time of measurement, i.e., 1997-98, years of protection were thirteen and eight for Basanta and Rapti, respectively. Rautiainen (1999) reported varying densities (2200 to 8700 stems ha^{-1}) in sal forest aged from 5 to 22 years. Another study (Rautiainen *et al.*, 2000) recorded 5911 and 9189 stems ha^{-1} in two five-year-old sal forests protected by local villagers. Although it is not mentioned, these two studies must have measured only those trees over a certain minimum dbh. But all plants taller than 1.37 m were measured in this study. Though Basanta and Rapti seem denser than the forests of afore-cited studies, the difference may lie only in the measurement procedure. Seedling density after one growing season following regeneration felling varied from 73 542 to 91 125 ha^{-1} (Rautiainen and Suoheimo, 1997), suggesting that Basanta and Rapti forests may have developed from similar seedling densities. It is likely that the present forest at Basanta and Rapti originated with much higher seedling densities and that stocking in the stands will continue to decline consistent with the stem-exclusion stage of stand development as postulated by Oliver and Larson (1996).

8.2 Treatment effects on stem growth

Lopping effects on increments (dbh, basal area, height and volume) of tree were tested for the following sub-sets for both forests:

- All surviving trees (all species combined)
- Sal trees
- Non-sal trees
- Dominant trees (two groups - largest dbh trees and tallest trees)

Tukey's test showed no significant differences (at 5%) among treatments (0, 40, 60 and 80% lopping) with respect to increments (dbh, basal area, height and volume) in any sub-sets of Basanta forest.

In Rapti too, one lopping up to 80% of tree height did not significantly decrease growth (dbh, basal area, height or volume) from no-lopping in any sub-sets except in dbh and volume of tallest-trees group, and volume increment of non-sal group. In contrast, 40% lopping significantly increased the growth of basal area (all, sal, and largest), height (sal), and volume (all, sal, and largest-trees) from no-lopping. Moreover, even 60% lopping produced significantly higher (at 5% significance level) growth of basal area and volume increment than no-lopping of sal in Rapti.

Lopping effects on plot-level increments (basal area and volume) were tested for the following sub-sets for both forests:

- All net (survivors + ingrowth - mortality)
- Survivors (all species combined)
- Sal net
- Sal survivors
- Non-sal net
- Non-sal survivors

Tukey's test showed no significant differences at the 5% level of plot-level increments (basal area and volume) among lopping intensities (0%, 40%, 60% and 80%) in any sub-sets of Basanta forest.

Lopping up to 80% did not significantly reduce growth of plot-level basal area and volume in any sub-sets in Rapti. On the contrary, 40% lopping increased the growth significantly in sub-sets (basal area of survivors, sal-net, and sal-survivors, and volume of survivors, sal-net, and sal-survivors). Even up to 60% lopping increased growth significantly for some sub-sets (basal area growth of survivors, sal-net, and sal-survivors, and volume growth of sal-net and sal-survivors).

This study has shown that one lopping event of up to 80% of tree height can be sustained in sal forest without significant (at 5% level) loss of growth (dbh, basal area, height, and volume in tree level and plot level). This result was found one year after lopping in all sub-sets in both forests, except the tallest-tree group in Rapti. The tallest-tree group in Rapti could sustain only up to 60% lopping without significant reduction of dbh and volume growth. On the contrary, up to 60% lopping increased growth increment significantly in some strata in Rapti (Tables 5.25, 5.29, 5.30, 5.36).

A single litter removal event did not produce any significant differences in stem growth in either forest. Elsewhere, it has been demonstrated that leaf litter in sal forest increased the uptake of all major nutrients (Pakrashi, 1991; Prasad *et al.*, 1991). Melkania (1998) reported that the removal of dead leaves from sal forests drained the nutrients and reduced the fertility and growth; similar results were asserted by Maithani *et al.* (1989) and Schmidt (1993). These studies were based on repeated litter removal and soil or litter nutrient analysis, which were not measured in the present study. Interactions between lopping and litter showed no significant differences in stem growth in either forest. The causes may be too short a period of growth following treatments and / or undetectable effects of single events.

In summarising the significant effects of treatments (lopping and litter), the study led to the following conclusions under the conditions of Basanta and Rapti community forests:

- One lopping event up to 80% did no significant harm to stem growth of sal forests in the one year following the lopping, except for that of dominant tall trees;
- Dominant-tallest trees in some forest stands, such as Rapti, can sustain only 60% lopping without negative effect on growth;
- In some situations, such as Rapti forest, one event of up to 60% lopping is significantly beneficial for stem growth in the period immediately following the event.

Answers to the following questions will lead to understanding the mechanism of lopping effects in sal forests in general, and Basanta and Rapti in particular:

- How could lopping up to 80% be sustained without deleterious effects on tree growth?
- Why did responses vary in the two stands?
- Why did the tallest trees in Rapti respond differently?

Some studies have measured lopping intensity as a percentage of live-crown length instead of tree-height as measured in this study. Ways of comparing these two methods need to be explored. Tables 4.5 and 4.10 gave the height of the lowest live-branch in Basanta and Rapti forests respectively; the average height at which the lowest live-branch was found was at 37% of tree height in both forests, indicating that the upper 63% of the tree height is within the live crown in the studied forests. In fact, lopping intensities 40%, 60% and 80% of tree height of studied forests will be equivalent to 5, 37 and 68% of live-crown, respectively.

Effects of lopping on diameter and height growth have been shown to vary with species, lopping intensities and environment. Some studies (Helmers, 1946; Stephens and Spurr, 1947; Gordon, 1959; Vuokila, 1960; Jemeson, 1963; Staebler, 1963; Bredenkamp *et al.*, 1980;

Sharma *et al.*, 1991; Pinkard and Breadle, 1998b) found no adverse effects on dbh and height growth following pruning (20-75%). However, other studies (Boggess, 1950; Young and Kramer, 1952; Bennett, 1955; Majid and Paudyal, 1992; Uotila and Mustonen, 1994) reported detrimental effects after pruning (35-80%). Still other studies (Barrett and Downs, 1943; Clark, 1955; Stein, 1955; Skilling, 1959; Bhimaya *et al.*, 1964; Deveaux, 1969; Eckstein, 1970; Popov, 1982; Tsiouvaras *et al.*, 1986; Bhat *et al.*, 1995; Gupta *et al.*, 1996a; LoCho *et al.*, 1997) recorded growth enhancement following pruning (30-100%). In this study, lopping 40 to 80% of tree height did not adversely affect the dbh and height growth at either site, except the tallest-trees group in Rapti. The tallest-trees group sustained only up to 60% lopping without adverse effects on dbh and height growth.

Based upon the differential effects of lopping on two different leaf-life-spans (evergreen and deciduous) species (see 2.3.6), the effects of lopping on most of the broad-leaved species were positive or at least not negative, whereas the effects of lopping were negative in most of the evergreen species. No significant adverse effects of up to 80% lopping on growth in the present research may have been influenced by the deciduous nature of sal forests of Basanta and Rapti. However, such differential effects were not supported always (Vanderklein and Reich, 1999).

Lopping in the present research was done during winter season. Studies (Sharma and Gupta, 1981; Falcioni and Buresti, 1997; Tewari, 1998; Kumar, 1999) indicated the superiority of lopping in winter over the lopping in other seasons, for tree growth. This may have contributed to tolerance of up to 80% lopping in the present study.

Some studies have found a positive correlation between enhanced photosynthesis and foliar nitrogen (Hoogesteger and Karlsson, 1992; Trumble *et al.*, 1993; Morrison and Reckie, 1995). Nitrogen content of sal progressively increases from the bottom to the top of canopy foliage (Pokhriyal *et al.*, 1987). Nitrogen moves towards the upper canopy, and the leaves in the lower canopy start the translocation process earlier (Pokhriyal, 1988; Pokhriyal *et al.*, 1988). Although nitrogen mobilisation was not investigated in the present study, another study (Pokhriyal, 1988) indicated that the translocation process was already started at the time (December-January) of lopping in this study (Figure 2.2). Nitrogen from the lower leaves must have been translocated to the upper canopy, and the lower leaves were most likely in the process of senescing. Lopping of the lower canopy may not have reduced the per-tree volume of foliar N from the tree, but reduced negatively contributing leaves.

Leaf senescence involves the process of retranslocation of N from old leaves to other parts of the plant (Kim *et al.*, 1991; Wendler *et al.*, 1995). Lopping has been reported to delay senescence (Trumble *et al.*, 1993; Pinkard *et al.*, 1998). Leaf water stress was reported as the cause for rapid senescence of *Sasa senanensis* (Lei and Koike, 1998) and *Sorghum bicolor* (Morgan *et al.*, 1993). Water stress induced leaf senescence (Ni and Pallardy, 1991; Raison *et al.*, 1992) and leaf senescence was delayed in flooded seedlings (Terazawa and Kikuzawa, 1994). Lopping may have improved the water status in the present study, and may have reduced water stress in remaining foliage, delaying leaf senescence. Information on senescence was not recorded in the present study. Delayed foliage senescence can have a positive effect on photosynthesis, and consequently improve growth rate (Dickson and Isebrands, 1991; Rahmani *et al.*, 1998). Foliage reduction increased photosynthetic capacity per unit leaf area of *Quercus rubra* seedlings grown in low-water, but not in high-water, regimes (McGraw *et al.*, 1990). Although the mechanism of how delayed senescence improves photosynthesis and growth is unclear, delayed senescence means that the leaves will be active in assimilation for a longer period. Further, delayed senescence may have resulted in extended translocatation of foliar nutrients back to the tree in the case of lopped trees (Kim *et al.*, 1991; Wendler *et al.*, 1995). Nitrogen reabsorbed from foliage before leaf abscission is a significant source of N for new leaves (Temple and Riechers, 1995). Eventually, delayed senescence could have promoted the growth of lopped trees.

While interpreting compensatory growth mechanism based upon the defoliation response of common ash, Collin (2000) found that partial defoliation was not sufficient to produce the required level of stress to induce a growth response; total defoliation induced the formation of more internodes than in the un-defoliated plant. Stress from defoliation of red pine seedlings interferes with plant carbohydrate and nutrient allocation and stimulates the rate of photosynthesis in remaining foliage, mobilisation of starch reserves, and eventually, carbohydrate production (Reich *et al.*, 1993). Such mechanism may have worked in sal, but experiments in the present study were not intended to explore these factors.

Treatment responses varied in the two experimental forests. Effects of lopping depend upon stand density (Bull, 1943; Helmers, 1946; Takeuchi and Hatiya, 1977). Pruning increased the growth in a closed Douglas-fir stand (Stein, 1955) but not in open-grown trees (Staebler, 1963). The denser the stand, the heavier the lopping that can be sustained before growth declines (Takeuchi and Hatiya, 1977; Kellomaki *et al.*, 1989). Light penetration through the canopy (described as a function of leaf area index) decreases exponentially with increase in canopy depth (Nobel *et al.*, 1993). The upper canopy would intercept the major portion of incident light, and only a low level of diffuse light would penetrate into the lower canopy. Accordingly, carbon assimilation and assimilate export would be low from the lower canopy, and the more dense the stand, the lower will be the assimilation. The results of the present study, with only two stand densities, is certainly in line with this general conclusion. Rapti (denser) forest was affected less (in fact, growth was increased) than Basanta (sparser).

Differential status of canopy closure between two experimental forests may have contributed in growth increment differently. Lopping may improve growth if lopping coincides with canopy closure (Pinkard and Breadle, 1998b). In the case of *E. nitens* trees following canopy closure, the height to the lowest green branch in the crown of unpruned trees was approximately the same as 50% (live crown) pruned trees at two years after pruning (ibid). The lower 50% of the crown could have contributed only insignificantly to the rest of the tree. On the contrary, leaves below light compensation layers contribute negatively to net photosynthesis (Labyak and Schumacher, 1954; Lehtpere, 1957; Reukema, 1959), and such leaves senesce, losing dry weight before death and abscission (Nobel *et al.*, 1993). Although canopy closure was not measured in the present study, Rapti was closer to canopy closure than Basanta (observation, and also supported by greater stocking and equal crown depth, i.e., per cent of tree height).

Moisture conditions may have contributed to lopping effects in the present study. Lopping, by reducing leaf area and crown density, reduces transpiration as an immediate response (Singh and Thompson, 1995; Teskey and Sheriff, 1996; Bandara *et al.*, 1999). The relationship between leaf water potential and transpiration for woody plants is curvilinear (decreasing resistance with increasing flux) (Kozlowski and Pallardy, 1997). The reduction in transpiration improves the plant water status for the remaining foliage (Wenkert, 1983; Myers, 1988; Kozlowski and Pallardy, 1997). Improved plant water status increases stomatal or intercellular conductance and enhances photosynthesis (Hodgkinson, 1974; Wallace *et al.*, 1984; Blake and Tschaplinski, 1986; Reich *et al.*, 1993; Morrison and Reckie, 1995; Singh and Thompson, 1995). In dry sites, where moisture is a limiting factor for growth, reduced transpiration may improve the growth by enhanced photosynthesis (Linder, 1985). Rapti, being drier and denser than Basanta, may have benefited more than Basanta from lopping. Furthermore, this effect may have prolonged the growing period in Rapti. However, lopping may encourage understory, increasing understory transpiration; canopy opening may result in soil surface evaporation, but these factors were not measured in the present study.

In the sal forests of this study, younger forest (Rapti) responded more quickly and to a greater extent than the older forest (Basanta). Smaller plants responded with greater photosynthetic enhancement than older plants (Reich *et al.*, 1993). Smaller plants responded earlier to pruning, but the response was shorter in duration (Hodgkinson, 1974). These two instances (i.e., Hodgkinson, 1974; Reich *et al.*, 1993) indicated that the higher the demand for assimilates, the greater the enhancement of photosynthesis. Increase in pruning severity increased photosynthetic enhancement (Alderfer and Eagles, 1976; Heichel and Turner, 1983;

Wallace *et al.*, 1984; Reich *et al.*, 1993; Pinkard *et al.*, 1998). In some cases, good association was encountered between CO_2 assimilation and rates of assimilate utilisation (Geiger, 1987). Some species indicated photosynthetic rates below their potential, and the low rate may have been regulated by the end-use, i.e., demand for assimilates (Hodgkinson, 1974; Heichel and Turner, 1983; Reich *et al.*, 1993; Pinkard and Breadle, 1998c). The differential effects of lopping between two forests may have been regulated by differential demands for assimilates.

Lopping response may have been related to the slower growth rates in Basanta than Rapti. On the basis of initial dbh, dbh growth rates in Basanta were 11.56%, 9.75% and 26% for all-species, sal and non-sal, respectively; growth rates in Rapti were 25.15%, 22.38% and 36.67% for all-species, sal and non-sal, respectively. It has been asserted that the level of lopping a species can sustain depends upon its growth rate; the faster the growth rate, the more rapid will be the recovery response (Pinkard and Breadle, 1998b).

Tallest trees in Rapti responded differently from other sub-sets. Lopping, by reducing leaf area density, increases the diffuse fraction of light penetrating into the canopy (Kira *et al.*, 1969). Pinkard *et al.* (1998) found no relation between photosynthetic response and changes in light environment. Their experiments were at the tree level, and removing lower foliage did not make any change in light environment in the crown of experimental trees. But the present study was in multi-layered stands, in which lopping changed the light environment, particularly in the middle-storey and below; the heavier the lopping, the greater the changes in light environment. Self-shedding in a forest stand may be one reason for low net assimilation rates (Vickery, 1972), and removal of higher-level leaves may result in improved carbon balance due to higher net assimilation rates (Verkaar, 1988). Such effects are reflected in Rapti. Trees in the middle-storey and lower layers may have been benefited and sustained up to 80% lopping without any adverse effect. But tallest-trees sustained only up to 60% lopping. So the foliage between 60 and 80 per cent of tree height contributed only in tallest-trees' group, but not in lower storeys (this portion in other storey may still have lower photosynthesis due to shading). This instance supports the effects of lopping caused by change in light environment.

Changes in photosynthetic responses to lopping have been attributed to change in stomatal conductance (Hodgkinson, 1974; Wallace *et al.*, 1984; Reich *et al.*, 1993; Morrison and Reckie, 1995), changes in hormone concentration or biochemical reactions (Caemmerer and Farquhar, 1984; Geiger, 1987). Study of these factors was not involved in the present work.

Besides growth, lopping increased the mortality (by frequency) in both forests. Mortality increased with lopping intensity and such effects have been reported elsewhere (Helmers, 1946;

Slabaugh, 1957; Skilling, 1959). However, treatment effects on mortality were not significant on the basis of basal area and volume in any strata in either forest.

In conclusion, changes in light environment, foliar N content, delayed senescence, growth rate, moisture status and various conditions relating to the enhancement of photosynthesis with increased demand for assimilates could have been the causes for capability of sustaining such a high level of lopping intensity in sal forests one year after one-event lopping. The same factors may have played roles in sustaining different levels of lopping intensities between the two forests. The different levels of lopping tolerance between mean trees and the tallest-tree group in Rapti can be explained on the basis of changes in light environment and proportions of productive versus non-productive foliage. The shorter the trees in a multi-layered stand, the higher the level of lopping they can sustain, because the crown of such trees will be under shade from taller trees and more of the foliage will be little or non productive. Tree density of 2000 ha^{-1} in a forest such as Rapti can have positive effects from lopping up to 60% of tree height.

Long-term effects of lopping and litter removal on growth in sal forests have rarely been studied. Tables 2.1 through 2.3 indicated that most of the adverse effects were observed within the first few years (one to six years), and no-effects and positive-effects were recorded over a relatively longer period (one to 20 years) after lopping. Adverse effects were recorded as immediate effects only, and lopped trees were recovered within a few (one to three) years after lopping (Helmers, 1946; Luckhoff, 1949; Takeuchi and Hatiya, 1977; Bredenkamp *et al.*, 1980; Koyama and Asai, 1998).

Repeated lopping reduced growth in some cases (Boggess, 1950; Sutton and Crowe, 1975; Pokhriyal *et al.*, 1994), and increased it in one (Bhimaya *et al.*, 1964). In all these cases, lopping was repeated within a short time after the first lopping, i.e., before the recovery period. Most of the adverse effects (Table 2.1) appeared within first few years after lopping, suggesting that annually-repeated lopping may not contribute to growth. Although positive effects of lopping were observed after one year in some cases in the present study, annually-repeated lopping may not be suggested without the clear understanding of the physiological causes of lopping tolerances in sal forests. The effects may be different if lopping is repeated after the trees have recovered.

Litter removal in two experimental forests did not produce any significant adverse effects. Studies have shown that severe cleaning of forest floor have caused depletion of nutrients in sal forests (Schmidt *et al.*, 1993; Melkania and Ramnarayan, 1998). This suggests that repeated (annual) litter removal may not be an appropriate prescription for sal forests.

8.3 Treatment effects on regeneration

Lopping resulted in significant changes in regeneration frequencies for all life-forms in both forests, except lianas in Basanta (Tables 6.27 through 6.29). The frequency changes with different lopping intensities are given in Figures 8.1 through 8.3, and following are general impressions from the present study.

- Sixty percent lopping produced the greatest increase (absolute) in total regeneration frequencies in both forests (Figure 8.1).
- Different life forms responded differently to lopping in the two forests (Figures 8.2 and 8.3).

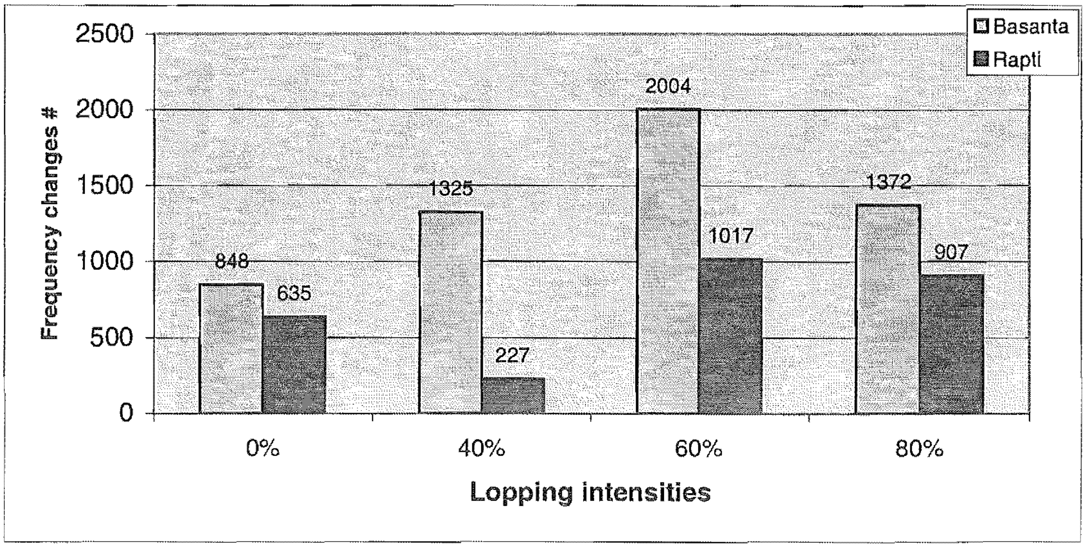

Figure 8.1: Frequency changes by lopping intensity both forests

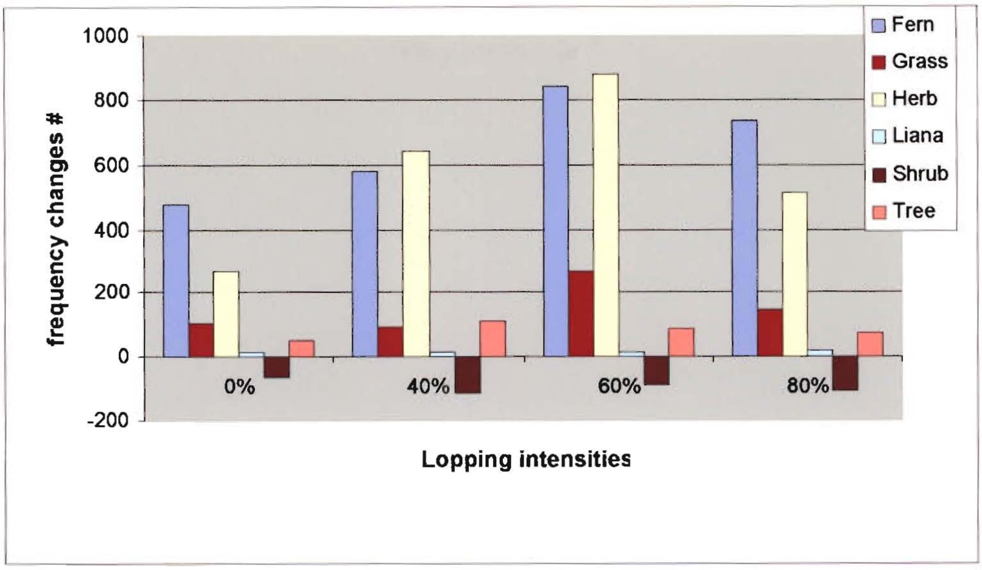

Figure 8.2: Frequency changes by lopping intensities and life forms in Basanta

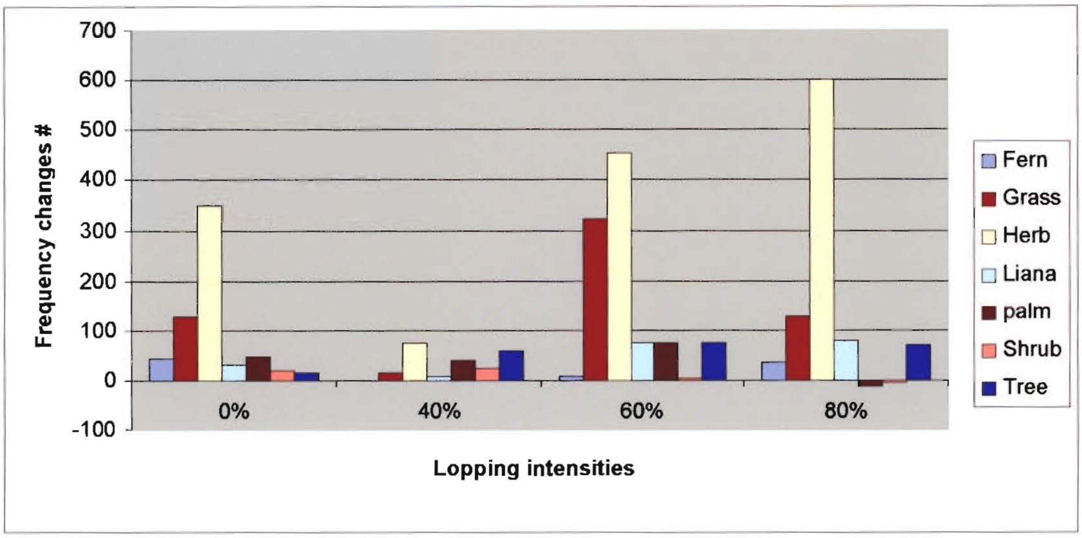

Figure 8.3: Frequency changes by lopping intensities and life forms in Rapti

Litter treatment produced significant results for regeneration of all life-forms except lianas at Basanta, and shrubs in both forests (see Table 6.27). Generally, litter removal increased regeneration over rates without litter removal. Regeneration of all life-forms except trees at Basanta and ferns at Rapti showed significant interactions between lopping and litter treatment.

8.3.1 Treatment effects on tree regeneration

Results of treatment effects on tree species (all tree species combined) and sal are presented in Figures 8.4 through 8.7. Lopping changed regeneration frequencies of trees in both forests, but two forests showed differential effects (Figures 8.4 and 8.5). For tree regeneration, interaction between lopping and litter-removal was not significant at 5% level of significance at Basanta but was highly significant at Rapti. Similar differential effects were produced in sal regeneration, too (Figures 8.6 and 8.7).

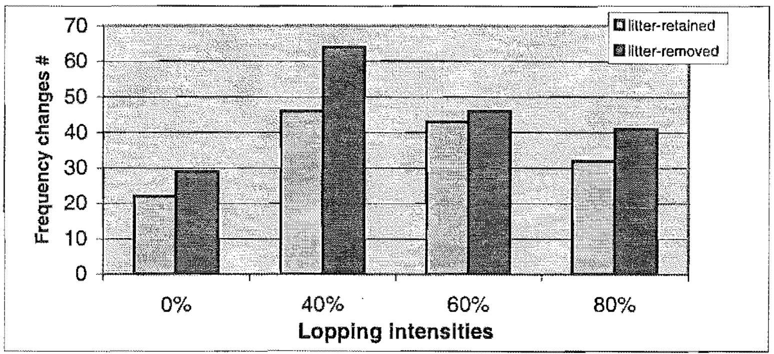

Figure 8.4: Treatment effects on tree regeneration frequency in Basanta

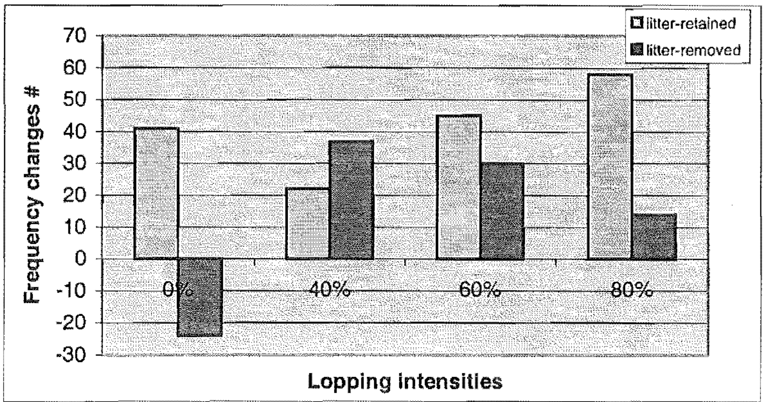

Figure 8.5: Treatment effects on tree regeneration frequency in Rapti

Besides differences in site, age and stocking, two forests of the present study differed in species composition; of the total frequency increase, sal constituted 85% in Basanta and 38% in Rapti. These differences may be attributed to differential effects of lopping and litter removal on tree regeneration in the two forests. Survival of tree seedlings in different canopy-opening varied with species (Everham *et al.*, 1996).

Lopping increased regeneration frequencies of all tree species and sal in Basanta, and sal in Rapti over no lopping; however, the effects on all tree species in Rapti were not a clear trend. Light-gaps or openings have been shown to enhance survival of tree seedlings (Minkler and Jensen, 1959; Grubb, 1977; Augspurger, 1983; Augspurger and Kelly, 1984). Canopy removal, leaving sub-canopy, midstory, and understorey, significantly increased light level for seedlings (Mesquita, 2000). Although the changes in ground-level light under lopping were not measured in this study, lopping certainly increased the diffuse fraction of light penetrating into the canopy (Kira *et al.*, 1969), and to the lower storeys. Light increase by lopping may have been responsible for increased frequencies of all tree species and sal regeneration frequencies in Basanta (Figures 8.4 and 8.6) and sal in Rapti (Table 8.7). Other studies made similar observations in sal (Qureshi *et al.*, 1968; Khan *et al.*, 1986; Troup, 1986) and other regeneration (Everham *et al.*, 1996).

Although lopping up to 80% increased all tree species and sal regeneration over no lopping in Basanta and in sal in Rapti, the increment decreased after 40% lopping (Figures 8.4, 8.6 and 8.7). Elsewhere high temperature inhibited the germination of Douglas-fir in clear-cuts (Caccia and Ballare, 1998), and low levels of natural regeneration stocking were observed in similar (high temperature) cases (Swanson and Franklin, 1992; Halpen and Spies, 1995). Decreases in frequency changes in over 40%-lopped treatments (Figures 8.4, 8.6 and 8.7) may be due to the inhibitory effect of temperature with higher lopping intensities. Sal seedling survived well in overhead light with little side-shade (Troup, 1986), so lopping over 40% may not have maintained sufficient side-shade in the present research.

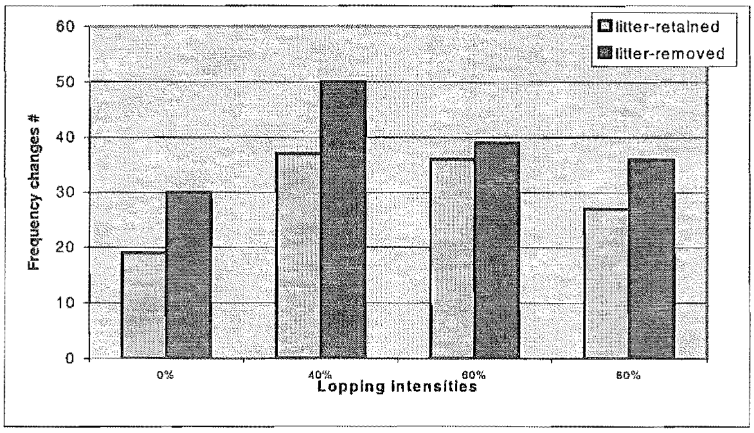

Figure 8.6: Treatment effects on sal regeneration frequency in Basanta

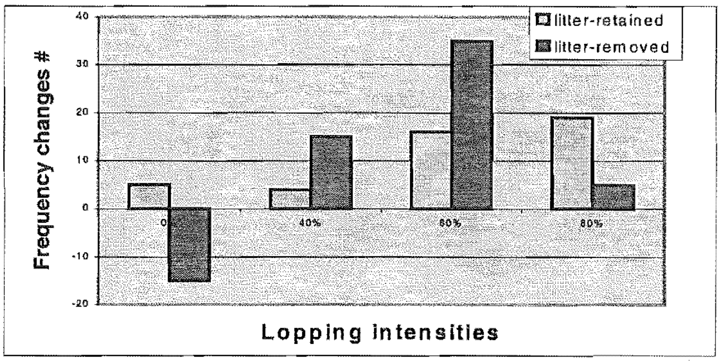

Figure 8.7: Treatment effects on sal regeneration frequency in Rapti

Litter removal altered the number of tree seedlings in both forests (Tables 6.10 and 6.11), but the two forests gave contrasting results, i.e., litter removal increased regeneration in all lopping intensities for both all-tree-species and sal at Basanta whereas litter removal decreased all-tree-species regeneration at Rapti, except at 40% lopping. However, litter removal in Rapti increased regeneration of sal in 40 and 80% lopping. Litter removal produced the greatest increase in regeneration at 40% lopping for all-tree-species in both forests, and sal regeneration in Basanta, whereas litter removal produced greatest increase at 60% lopping in sal regeneration in Rapti. The results for the regeneration of trees (all species) and sal are not different at Basanta, but for sal regeneration at Rapti, litter removal increased regeneration most under 60% lopping. Effects of litter on regeneration vary with species, and could be altered within a species by habitat differences and by complex interactions with other environmental and biotic factors (Molofsky and Augspurger, 1992; Everham *et al.*, 1996).

The differential effects of litter removal between two forests may have been due to the temperature and moisture status of two forests. Mean temperature and evapotranspiration were slightly higher in Rapti than Basanta (Figures 3.2 and 3.3). Presence of leaf litter reduces the incoming radiation that reaches the soil surface and prevents large increase in soil temperature (Molofsky and Augspurger, 1992). Litter-less pits were found significantly warmer and drier than litter-retained pits in deciduous forests (Beatty and Sholes, 1988) and pine plantation (Smethurst and Nambiar, 1990). In heavily lopped sites in Rapti, removal of litter might have raised the soil temperature inhibiting germination (Caccia and Ballare, 1998). As reported elsewhere (Molofsky and Augspurger, 1992), retention of litter in heavily lopped sites in Rapti must have resulted in higher humidity and moisture. Moisture stress may have been greater at Rapti than Basanta, due to higher mean temperature, evapotranspiration and stocking. But decrease of regeneration of both all tree species and sal by litter removal in no lopping treatment in Rapti may not be explained by temperature alone, as litter removal has increased frequencies by 40% in all tree species and by 40 and 60% lopping in sal regeneration.

Although high light and litter seem to be generally good conditions for regeneration, the regeneration and survival results depended on the size of seeds (Everham *et al.*, 1996). Small seeds may not be able to penetrate the litter layer (ibid.), or seedlings may die immediately being unable to reach soil (Troup, 1986). The influences of leaf litter on regeneration, however, depends on type and depth of litter (Abbott, 1984). Large-seeded oak regeneration was found more on plots with the thinnest litter, and in openings rather than under the canopy (Minkler and Jensen, 1959). In contrast, the presence of litter and moss appeared to be necessary for Douglas-fir regeneration in open area (Jones, 1945). These instances are in line with the case of Rapti, which showed the significant interaction effects of lopping and litter.

High light is good for regeneration only when desiccation risk is low; litter retains moisture. Litter removal in heavier lopping (60 and 80% for all-tree-species, and 80% for sal) decreased regeneration at Rapti.

Pathogens commonly cause mortality among tropical tree seedlings, and vary with tree species depending upon their light tolerance (Augspurger and Kelly, 1984). Fungal pathogens of seedlings are known to be favoured by low sunlight, high humidity, and moderate temperatures (Weber, 1973; Rotem, 1978), conditions of the shaded understory of tropical forests (Bazzaz and Pickett, 1980; Garwood, 1983). Light contributed to seedling escape from pathogens for almost all of the 18 species studied, and light-gaps significantly reduced pathogen activities (Augspurger and Kelly, 1984). Baruah and Bora (1995) recorded different types of fungal populations in leaf litter in sal forests, and increased litter moisture content increased the diversity of the fungal population. Increase of regeneration frequencies with lopping in the present study may have resulted in part from reduced pathogen activities with greater light exposure.

The two forests of the present study responded differently for regeneration frequencies of tree species to the lopping intensities; forty percent in Basanta produced maximum increase whereas 80% produced maximum in Rapti. Seed/seedling predation rates by animals and microbes vary with gaps (Grubb, 1977), and such rates are frequently higher under intact vegetation than in open areas (Gill and Marks, 1991; Myster and Pickett, 1993). Variability in predation in time and space is bound to contribute to the variation in the numbers of viable seeds present at the time of formation of a particular gap (Abbott and Quink, 1970). Such results may have been due to the reason that higher density increases disease levels, especially under shaded condition. Rapti forest, being denser than Basanta, responded with higher regeneration under heavier lopping than in Basanta forest.

At 60% lopping in Rapti, litter removal increased sal regeneration but decreased all-tree-species regeneration. Myster and Pickett (1993) found reduction of predation rates by adding litter in the forest; in contrast Caccia and Ballare (1998) found that the presence of a litter layer that completely covered the seeds did not affect predation rates. The contrasting findings of Myster and Pickett (1993) and Caccia and Ballare (1998) give insight into two scenarios of predation which may be relevant in some ways for the contrasting results between all-tree-species (Figure 8.5) and sal (Figure 8.7) at 60% lopping in Rapti. But sal or non-sal seed predators have not been studied (not available in accessible literature).

Some species can regenerate from seed that has been in the soil for decades or more, whenever and wherever a gap arises in the forest, formed by tree-falls or branch-falls (Grubb, 1977). It is very common that sal propagates from suckers whenever and wherever the environment is favourable, i.e. when grazing and fire are controlled. Lopping may have contributed to this result, but seedlings from seed and suckers were not distinguished in this study.

8.3.2 Effects on non-tree species regeneration

Treatment effects on non-tree species regeneration changes are summarised in Figures 8.8 (Basanta) and 8.9 (Rapti). In both forests, interaction between lopping and litter removal resulted in highly significant effects on regeneration of non-tree species. Sixty per cent lopping and litter-removed produced maximum frequency increases in both forests, but minimum values occurred in different combinations of treatments. Lopping alone (comparing all litter-retained treatments in both forests) did not produce significant changes, but litter removal increased frequencies in all lopping intensities in both forests, except no lopping in Basanta. The present study confirmed early observations that the relationship between litter and ground flora is negative (Sydes and Grime, 1981a).

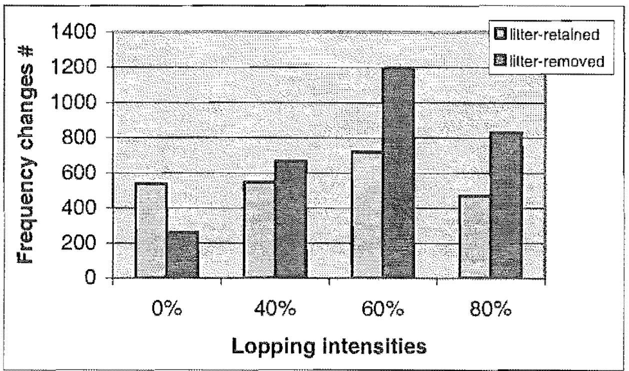

Figure 8.8: Treatment effects on regeneration frequencies of non-tree species in Basanta

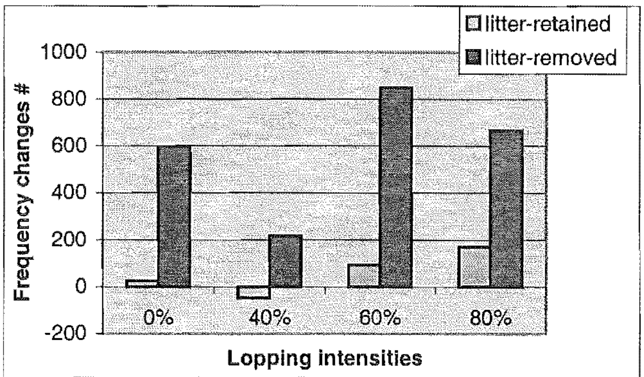

Figure 8.9: Treatment effects on regeneration frequencies of non-tree species in Rapti

Among life forms of non-tree species, herbs (both forests combined) were 38% and 42% of regeneration in 1997 and 1998, respectively. Treatment effects on herbs are presented in Figures 8.10 (Basanta) and 8.11 (Rapti). In Both forests, litter removal increased regeneration in all lopping intensities except no lopping in Basanta. Furthermore, the higher the lopping intensity, the higher the increase in regeneration frequency of herbs with litter removal, except 40% lopping in Rapti. Litter removal encouraged several herbaceous species to expand their distribution from mounds into tree-fall pits in a deciduous forest (Beatty and Sholes, 1988).

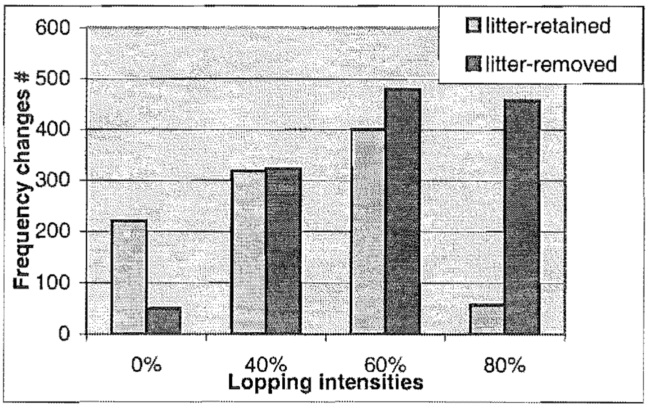

Figure 8.10: Treatment effects on regeneration frequencies of herbs at Basanta

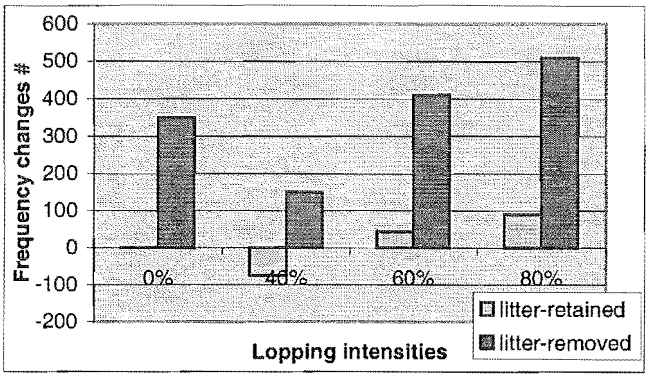

Figure 8.11: Treatment effects on regeneration frequencies of herbs at Rapti

Ferns at Basanta was accounted for a major segment of non-tree species (31% and 40% in 1997 and 1998, respectively). Lopping increased the regeneration of ferns in Basanta, and litter removal increased regeneration in all loping intensities, except in 80% lopping (Figure 8.12). Grasses formed 12% and 16% of regeneration in 1997 and 1998, respectively, in Rapti. Litter removal increased regeneration of grasses in all lopping intensities, except at 40% lopping (Figure 8.13). Both of these cases, i.e. ferns in Basanta and grasses in Rapti, showed in increase in regeneration with litter removal. A safe site for regeneration of grass species was found free of litter, and even a small amount tended to have negative effects (Fowler, 1988). Seedling survival of a palm species (*Astrocaryum murumuru*) was significantly affected by leaf litter, with more seedlings in shallow rather than deep litter (Cintra, 1997). In contrast, litter has been shown to increase seedling survival in arid environments (Evans and Young, 1970), indicating the differential effects of litter on regeneration and survival depending upon the environment.

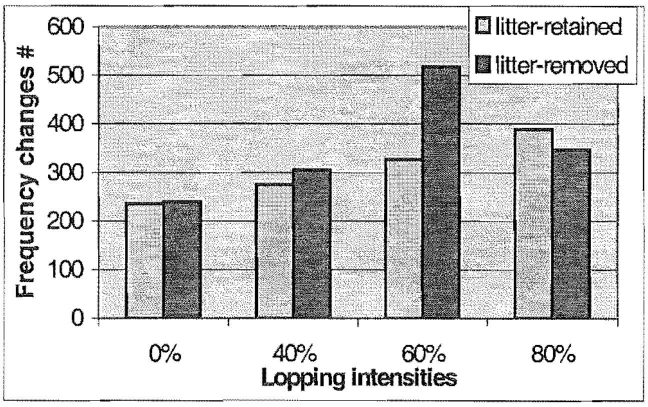

Figure 8.12: Treatment effects on regeneration frequencies of ferns at Basanta

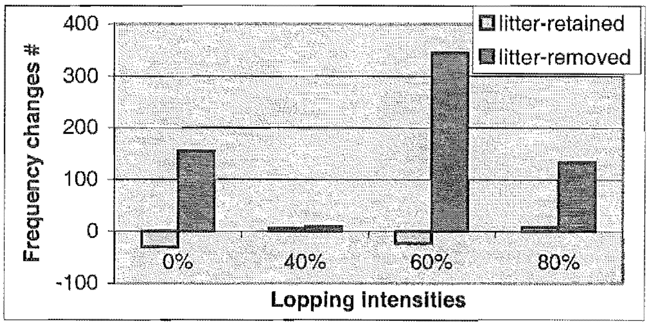

Figure 8.13: Treatment effects on regeneration frequencies of grasses at Rapti

In most of the cases of non-tree species (Figures 8.8 through 8.13), litter removal increased regeneration frequencies. Sydes and Grime (1981b) encountered most abundant litter within low-lying plain areas as compared to slopes. Litters from broad-leaf forests were found relatively mobile due to wind conditions (Orndorff and Lang, 1981), and the distribution of such litter mostly depended on the capacities of vegetation to trap and retain litter, mainly topography and ground stocking (Sydes and Grime, 1981a). The denser the stocking, the more the capability to trap litter. Basanta forest lies on slopes and Rapti in a low-lying plain; Basanta forest has sparser density than Rapti forest. The effect of litter removal was more pronounced in Rapti; removal of litter increased the regeneration frequency in Rapti far more than in Basanta.

The reasons for the negative effects of litter are not clearly known, but the following causes were encountered while studying regeneration of grass species (Fowler, 1988):

- Physical barrier
  - Causing seeds to germinate in the litter above ground
  - Shading to those that germinate beneath the litter
- Harbouring pathogens
- Fostering pathogens by an increase of soil moisture and surface humidity

The aspects listed above were not studied in the present study. A disturbance, such as lopping, could have an impact on litter effects on regeneration (Vogt *et al.*, 1996), but the litter added from lopping contained mostly leaves and twigs, which fall annually (in case of sal forests) to the ground even in the absence of lopping. However, branches were also felled in some cases, so lag effects may have contributed to some extent (howsoever little it be) in litter-retained (where litter including the lopped material was left in the plots) plots but was not studied in the present research. The results showed that canopy and leaf litter directly affected the regeneration of non-tree species, and these are mainly due to the alteration of microclimatic conditions (Fowler, 1988).

In summarising the treatment (lopping and litter removal) effects on regeneration, lopping and litter treatments increased regeneration of tree and non-tree species, in general. Although interaction between lopping and litter removal was significant in most of the cases in both forests, lopping in Basanta and litter removal in Rapti respectively contributed relatively more to regeneration changes. These results suggest that lopping in older forests and litter removal in younger forests might be tools for immediately enhancing regeneration. Effects of repeated lopping and litter removal, and long-term effects of single events, have not been studied. However, repeated removal of litter resulted in growth of weedy, herbaceous species in sal forest (Melkania and Ramnarayan, 1998), indicating that the repeated litter removal may affect the tree growth adversely.

8.4 Indigenous knowledge

Sections 8.2 and 8.3 indicated the possibilities and constraints of manipulation of foliage (lopping and litter removal) in sal forests based upon the effects on tree growth and regeneration. Experiments showed the possibilities of intervening (lopping and/or litter removal) in sal forests for increasing regeneration of most life forms, without adversely affecting tree growth.

Details of products from the sal forests are listed in Tables 7.6 through 7.8 and in Appendix VI. Users are seeing the forests as sources of a variety of products for their daily needs. Products (Tables 7.6) from different plant-parts (Table 7.7) belonging to different life-forms (Table 7.8) are being used by the users in both forests. Users' evidence showed the enormity of multiple-product production from Basanta and Rapti forests. Sal forests have been the source of a variety of products for rural people in Nepal and elsewhere (Prasad and Pandey, 1987a; Malhotra *et al.*, 1990; Rajan, 1995; Gautam and Devkota, 1999). Following uses (other than wood) of a sal tree were recorded while collecting indigenous knowledge:

> Sal foliage is good fodder, and sal leaves are used widely for making plates. The importance of sal leaves in social and religious gatherings is known for everyone, and its market values are also expressed by some users. Some of the users use sal leaves to make local cigarettes (wrapping around ground up tobacco leaves). Medicinal values of sal are known to most of the old people in general and local healers in particular. Latex, fruit, bark, inner epidermis (interior skin) of bark, flower and seed are used for treatment of various diseases. Latex is also used for aromatic purpose, and bark extract is used for wood preservation. Spiritual use of a sal tree was also expressed. Sal seed used to be used for making local wine, but these days seeds are mostly sold for industrial use. Although people do not know the industrial use of the flower, they are aware of its export market from a nearby town, Nepalgunj, to India.

Present research demonstrated the possibility of increasing regeneration through lopping and litter removal treatments in sal forests. Besides increase of sal regeneration, lopping treatment increased regeneration of multiple-product species such as *Orchis incarnata*, *Phoenix dactylifera*, *Terminalia alata* and *Diospyros malabarica* (see Appendix VI for multiple uses of respective species).

> Panchpate (*Orchis incarnata)* was recorded in both forests, and more frequent in Rapti. Panchpate leaves are used mostly in feeding goats. Roots are used as medicine, especially for livestock. As users still feel sufficient population of this species for medicinal use, management of this species would improve the fodder for goats. Users are familiar with some of its silvicultural characteristics such as tangling with tree. The experiment showed insignificant effects from lopping (5, 4, 2 and 9 plants in 0, 40, 60 and 80% lopping, respectively) in Basanta. However, lopping increased regeneration of panchpate in Rapti (19, 26, 52, and 40 at 0, 40, 60 and 80% lopping, respectively). In

both forests, litter removal reduced the frequency of regeneration (12 versus 8 plants in Basanta and 95 vs 42 in Rapti).

Leaves are the most frequently used plant part followed by the whole-plant, fruit and stem (Figure 7.1). Besides fodder, leaves are used for compost, fibre, food, medicines, spiritual objects and utensils. Major use of the forests (by number of species and plant parts) has been for fodder (120 species) followed by medicinal uses (67 species) and food (55 species) (Table 7.7).

Leaves of 70 species were used for fodder, and this indicates the importance of lopping in sal forests. Besides fodder from leaves of trees, shrubs and lianas, fodder is collected from ground flora such as grasses and herbs. Users demonstrated knowledge about the fodder quality of all species in their forests, and compared quality of fodder - very good fodder, good fodder, fodder, leaves palatable, fodder for certain period of the year, increases or decreases milk yield, causes dysentery or other disease. Also they specified the species for certain types of livestock, and appropriate timing of lopping (see Appendix VI). Elsewhere, villagers have demonstrated similar knowledge about trees on their farmland (Rusten, 1989; Rusten and Gold, 1991; Thapa, 1994).

Operational management plans for Basanta and Rapti prohibited grazing in the community forests (BHCFUG, 1996; RCFUG, 1996), but reducing livestock population (data not collected) was neither a desired option for users nor was it possible within a short span of time. Shifting from grazing to stall-feeding was not easy and instantaneous, and some instances of unauthorised grazing on the fringes of the forests were observed. Strong pressures from the users were recorded (not documented in this thesis) to incorporate the fodder supply in forest management planning. Observation of some illicit (i.e., not prescribed in management plan) lopping in Rapti reflected the situation (see Chapter V). Similar expressions were encountered regarding litter collection.

Besides identifying products for direct use, users also have traced the market opportunities of different products from sal forests, but operational management plans have not duly considered such aspects (Appendix VI). Shortcomings in operational management plans about the management of multiple products may have been due to lack of information about the products and/or inadequate knowledge on silvicultural regimes of multiple products.

As indigenous knowledge provided the information on many potential products from sal forest management (Appendix VI), local users demonstrated their knowledge on many aspects of the silviculture (ethnosilviculture) of many species in sal forests (Tables 7.9, Appendix VII). Ethnosilviculture knowledge covered all life forms of sal forests (Table 7.10).

Knowledge of forest products from a forest, and ethnosilvicultural knowledge among the users, could be very relevant in management planning of any forest or developing any silvicultural regimes for a particular forest. Community forest management, which focuses on multiple products and recognises their value to all sectors of users, needs to involve users in planning and implementing forestry activities. It is very important to understand the distribution of indigenous knowledge among different groups within a user group. The present research has investigated the socio-economic groups holding such knowledge, and analysed the relationship between socio-economic status and type of the knowledge in Basanta and Rapti.

Proportions of responses between men and women varied in the two forests. Out of 51 respondents in Basanta, 26 (51%) were women, and of the 354 responses from Basanta users, 58 and 42% were from female and male users, respectively. In Rapti, although women respondents were 18 (44%) out of 41, their responses comprised only 12% of the total 562 responses. The results reflect the differential levels of women's participation in the two forests. The differential levels of participation indicate that just including women or men as key informants may not mean their participation; the actual participation is better indicated by number of responses (as in the present research). The present research did not explore the reasons for such differences; however, it has been elsewhere reported that socio-economic situations may affects level of participation (Hobley, 1987; Britt-Kapoor, 1994). The differences such as composition of ethnic groups, income sources, location and exposure to external agencies (Chapter IV) may have resulted in differential level of responses between Basanta and Rapti. It can be, however, asserted that homogeneity of ethnic composition and income sources may have resulted in more participation of women in Basanta than in Rapti.

On the basis of the χ^2 test for association between categories of information and gender, the following were significant:

- Females demonstrated more knowledge of forest products than silviculture in combined analysis (both sites) and at Basanta.
- Males have more knowledge of silviculture than forest products in combined analysis and at Basanta
- Males have more knowledge of forest products than silviculture at Rapti
- Females have more knowledge of silviculture than forest products at Rapti.

The afore-mentioned statements suggest that knowledge types between genders varied between the two forest users groups. Studies from Nepal and elsewhere (Rusten, 1989; Tulachan and

Batsa, 1994; Samaniego and Lok, 1998) have reported that women had more knowledge of domestic trees while men had more knowledge of trees in public forests. Although men and women had similar knowledge of the plant parts used for medicinal purposes, women were more informative on preparation and application (Ochoa *et al.*, 1999). Evidence is encountered of men and women sharing a similar level of knowledge about tree and forest use (Rusten, 1989; Flaherty and Filipchuk, 1993). The knowledge between males and females cannot be generalised, but varies with the socio-economic factors, such as ethnicity, income, and location.

The present study indicated that respondents aged over 50 years indicated more knowledge of silviculture; however, age was insignificant for knowledge of forest products. Similar instances were encountered elsewhere (Mahat, 1985; Rusten, 1989).

Magar and occupational groups showed more knowledge of silviculture than forest products in combined (both FUGs) and Rapti. B/C and indigenous groups showed more knowledge of forest products than silviculture in combined, whereas B/C and other hill people showed significantly more knowledge of products than silviculture in Rapti. The association was not significant in Basanta. The results may have been influenced by the unbalanced number of respondents from all ethnic groups.

Income groups' association with knowledge categories was found significant in Rapti, where the situation is more heterogeneous than in Basanta. Wage-earning respondents were found more informative about silvicultural aspects than about forest products, and farming groups more about forest products than silviculture. However, wage-earning group revealed more knowledge in all knowledge categories in both forests based on number of responses. Wage-earning groups in Rapti were mostly involved in either farm or forestry related work, such as collection of timber and non-timber forest products.

Small landholders showed more knowledge in all categories in both forests. Landless showed more knowledge of silviculture than forest products, whereas land-holding groups (small and large) showed more knowledge of products than silviculture. Large landholders hold a relatively low level of knowledge on forest use and silviculture, as they generally intend to become independent of public sources (Rusten, 1989), by raising private resources (although tree resources in private land were not studied in this study, they are very different from forest species and management regimes) or using alternatives, e.g. agricultural residue for fodder and fuelwood.

On the basis of gender, caste, income and landholding association with knowledge group (use and silviculture), the present study cannot reject the hypothesis that "the poor of the community hold a larger portion of ethnosilvicultural knowledge than the wealthy".

8.5 Synopsis of discussion

Section 8.1 compared characteristics of Basanta and Rapti (based on Chapter IV) with other studies of sal forests elsewhere. Sections 8.2 (based on Chapter V) and 8.3 (based Chapter VI) indicated the possibilities of managing sal forests for multiple products i.e., canopy can be manipulated without affecting stem growth in the short term. The results showed that lopping is not only suggested for production of fodder, fuelwood or other NTFPs from foliage but also helpful for stand development (lopping enhanced growth in Rapti) in some cases. Furthermore, lopping and litter removal encouraged regeneration, indicating prospects for multiple products (treatment appropriate for increasing regeneration of desired species can be applied).

Understanding the users need and their priorities for different products and values could be prerequisite for sustainable forest management. Indigenous knowledge of forest products reflects the values from users' long experience. Users identified the range of the products from sal forests. Forest management should consider the forest products important to the users; importance depends upon the location, ethnicity, income, landholding, age and gender of the users. All sectors of the community demonstrated some sort of knowledge of forest products and ethnosilviculture irrespective of gender, income, landholding, and ethnicity; excluding any sector of the community may result in neglecting some product from the forest management. Neglecting some product may challenge sustainability of the forest management. Forestry professionals should focus themselves in sustainable use of forest products identified by users, which can be achieved only through users' participation.

Silviculture is a scientific art of producing desired forest products in a given situation (see section 2.3). Production of desired products is the main objective of silviculture. So the designing of any silvicultural regimes will be initiated from the identification of desired products from a particular forest. Ethnosilviculture is the technical knowledge evolved from continuous relationship (actions and interactions) between users and forests, and this could be the basis for further experimental investigation. Understanding ethnosilviculture and silvicultural experiments can be complementary and collaborative. Ethnosilviculture gives basis for silvicultural experimentation, and in this way users' knowledge can benefit from scientific knowledge. Collaborative approach in managing community forests may work towards users' stake in ensuring the productive development of forest resources to meet primarily their own needs, for direct consumption or personal income generation.

Investigation on indigenous knowledge of plant products has identified the range of plant products and uses from a sal forest, which contributes to setting goals for forest management. This information is essential to design silvicultural actions, i.e., producing multiple products, for users' participation in community forest management. Ethnosilvicultural information gives insights into the production of multiple products from sal forests, and a basis for experimentation to carry out favourable disturbances in forest stands. Accordingly, experiments on lopping and litter removal have indicated the potential supply of foliage (green and dead) from sal forests, and the potential for producing multiple products from the understory, without reducing tree growth. Although findings are based on short-term results, they may form the basis for longer-term management. Continuation of these experiments generates information in understanding appropriate intensity and frequency of lopping and litter removal, and such information are desperately required in actively managing sal forests that are or are being entrusted to local users. In lack of scientific results, the forests are either prohibited lopping and litter removal or conservatively implemented reducing benefits to the users.

CHAPTER IX. CONCLUSION: MANAGEMENT IMPLICATIONS

Sal forest covers over 11 million hactares, extending over Bangladesh, India and Nepal. This type is among the most productive forest in this region, and also the most accessible. Sal forest management has been a major concern of forest policy in the past, mainly for its timber quality. Forestry research in the past focused on the production of timber from sal forests. Considerable work has been done on regeneration, thinning and improvement felling (Troup, 1952; Champion and Seth, 1968; Tewari, 1995), but only focusing on the timber production.

The ecological zone of sal forest is heavily populated, and the majority of the population are subsistence cultivators. These forests have to meet the timber and NTFPs demands of local people. Understanding the multifaceted role of forestry in this region, the community or participatory forestry has been a major focus of management for the last two decades (HMG, 1989; Lai and Jarvis, 1991; Ganguli, 1995; Banerjee and Mishra, 1996; Khan, 1998; Banerjii, 1999; Bhatia, 2000). Fodder and leaf litter are among the main forest products for agricultural production in subsistence farming in this region (see Figures 1.1 and 1.2).

The majority of the population who are relying on subsistence farming in Nepal will be continuing on it, as no other option seems promising for the near future. Subsistence farming in Nepal is linked with the livestock population in primary energy conversion systems on farms (Rusten, 1989; Malla, 1992; Thapa, 1994). The livestock population is increasing (CBS, 1998), and the increase is projected to be 47% in 20 years (BPP, 1995), although livestock population per household is reported decreasing in the vicinity of the study (Gentle, 2000). The increasing livestock population increased the demand for fodder and bedding material, i.e. litter (Malla, 1992). As stated earlier (section 1.1), the forest will have to meet a large proportion of the fodder demand. Lopping of forests may not be avoided. Accordingly, management objectives of community forestry need to be oriented to supplying fodder from forest throughout the year.

Fodder collection from the forest (undergrowth and tree fodder) is throughout the year in varying quantity. Users collect more fodder from forests mostly when they have free time from farm activities. During busy farm activities such as planting and harvesting, they collect fodder from their own household sources. Landless or small landholders, too, are mostly engaged in planting and harvesting activities for wages earning, and look for nearby fodder resources during this time. Only those who have no private fodder resources collect fodder from forests during the busy period of the year. Most of the tree fodder is collected after crop harvest (major crops are harvested in Nepal in November/ December) and before the crop planting (May /June).

Sal foliage is collected mainly in November-January and April-July. As most of the other fodder species of sal forest initiate leaf shedding before sal, fodder from sal foliage is very important during winter, i.e., November-January. New leaves of sal are used widely for fodder from April to July. Depending upon the availability of tree species in the particular forests, users collect fodder from different species, e.g., *Schleichera oleosa* (October-May), *Terminalia alata* (October-March), *T. chebula* (October-November), *Pieris formosa* (December-March).

The objective of this study was to better understand how the demand for multiple products could fit in the silvicultural regime of sal forest; how they could be managed for different socio-economic groups in a community. It is clear (from Chapter One and Two) that silvicultural regimes for sal forests cannot be complete without consideration of lopping effects, and this study has investigated lopping effects in two forest stands. Although findings from this study cannot be generalized over the entire region, they may be useful in some ways to any sal forest depending upon the local conditions. Furthermore, the findings may also be relevant to some extent to any other forest types under participatory management.

9.1 Management regimes

Silvicultural pruning as a tool for increasing the value of final crops (mainly clear wood) has been an established practice since early-1900 (Barrett and Downs, 1943; Bennett, 1955; Shepherd, 1986). Clear wood production is maximised by early and severe pruning. Pruning reduced the height and diameter growth of some pines, and also lowered the dominance status of pruned trees (Luckhoff, 1949). In contrast, some species increased growth following pruning (Clark, 1955; Stein, 1955). Effects vary widely with species, sites and ages. Attempts have been made to investigate the appropriate level of pruning intensity (Pinkard, 1997), but most of the pruning regimes have been developed in plantations focussing only on the stem growth. Little is known about the pruning effects on the growth of multi-strata stands or understory regeneration. This research investigated the effects of lopping on stem growth and regeneration in sal forests, and explored the indigenous knowledge of multiple-products from sal forests.

Experiments in two sal forests showed that lopping up to 80% of tree height in one lift did not produce adverse effects on stem growth in either tree or stand level during the first year following the lopping. However, the two forests responded differently, indicating that this prescription will not be generally applicable to all sites or sets of environmental conditions of sal forests. Furthermore, trees in different canopy strata in a forest have responded differently. Depending upon the importance of by-products the following treatments (one event) can be prescribed:

- When the lopped product, i.e., foliage, is the priority of management, lopping can be done up to 80% of tree height in sal forest with stand characteristics (density, dbh, height) of either Basanta or Rapti.

- When the density is not more than 2000 stems ha^{-1}, lopping can be done only up to 60% of tree height without adverse effects on tree growth.

- When the stand is dense, i.e., more than 28,800 stems ha^{-1}, lopping up to 60% increases the growth increment significantly.

Litter removal did not produce any adverse effect on stem growth in the one-year following the treatment in either forest; neither did interaction between lopping and litter removal produce significant adverse effects on stem growth. From the results of present research, it is logical to allow one-time litter collection from sal forests, which is an important subsistence product (Bajracharya, 1983; Mahat, 1987; Gilmour and Fisher, 1991; Dhyani, 1998; Maikhuri *et al.*, 2000; Nayak *et al.*, 2000).

Lopping increased regeneration frequency in most of the life forms in both forests (Chapter Six). Sixty-percent lopping produced the greatest increase in both forests. Litter removal increased regeneration frequencies in most of the life forms in both forests. Moreover, lopping and litter removal interacted significantly in regeneration in the sal forests of this study. Depending upon the objectives of management the following general guidelines are recommended:

- Tree products are used for all use categories in Basanta and Rapti (Table 7.8), and treatment effects on regeneration are very important in managing community forests. Forty-percent lopping gives the highest tree-regeneration frequency in Basanta whereas no lopping produces the lowest regeneration. Litter removal has increased regeneration, but the interaction between lopping and litter removal was not significant in Basanta. This is valid for sal-regeneration frequencies, too. So, 40% lopping and litter removal can encourage the regeneration of tree species in environments like that of Basanta. In Rapti, 80% lopping without litter removal produces the highest tree regeneration frequency whereas 60% lopping and litter removal produces the highest regeneration of sal. No lopping and litter removal yielded the lowest in both tree and sal regeneration frequencies.

  In both forests, sal regeneration frequency was maximum in litter-removed plots, although lopping intensities for maximum sal regeneration were different, i.e. 40% in Basanta and 60% in Rapti. In both forests, minimum sal regeneration was in no-lopping plots. So for enhancing sal regeneration, lopping (intensity varies with forest density) and litter removal seems essential. For other tree species, lopping is necessary and litter may have to be retained to conserve moisture (as maximum regeneration of tree species in Rapti is in litter-intact plots, and only 51-55% of tree regeneration is of sal in Rapti). Thus, manipulation of lopping intensity and litter removal depending upon the stem density and species composition are very crucial for ensuring regeneration of tree species in general and sal regeneration in particular.

- Non-tree species includes (in the present study) fern, fungi, grass, herb, liana, palm and shrub; non-tree species form the major proportion of non-timber forest products in Basanta and Rapti. Sixty-percent lopping and litter removal produces the highest non-tree-regeneration frequency in both forests; however, results vary with life forms.

  Twenty and 17 species of herb have been used by the users for fodder and medicinal-use, respectively. In both forests, maximum regeneration is in lopped (60% in Basanta and 80% in Rapti) and litter removed plots.

  Twenty-one and 13 species of liana have been used for fodder and medicinal-use, respectively. Loping and litter removal did not make any effects on regeneration of liana in Basanta, but 80% lopping and litter removed plots increased significantly in Rapti.

  Grasses are high potential source for fodder supply in the community, and 18 species have been used for grass in the studied area. Sixty-percent lopping and litter removal plots resulted in highest regeneration of grass species.

  Shrubs are used in 12 out of 16 broad uses (Table 7.8). Shrubs have maximum regeneration in no lopping plots in both forests. Litter retained in Basanta and litter-removed plots in Rapti produced the highest regeneration. No lopping of sal forest leads to increased shrub regeneration.

Depending upon the objectives of management, lopping and litter removal regimes may be effective to increase or decrease the regeneration of some desired life form or species. One-event lopping up to 60% and litter removal is recommended for Basanta and Rapti for supplying fodder and litter without adversely affecting tree growth. Such treatment may result in increase of regeneration of some desired multiple-product species. However, the cycle for repeated lopping and litter removal needs to be further investigated.

9.2 Indigenous knowledge

Although the sal forest was seen by policy as a source of timber alone, this study shows that sal forest is a source of a variety of products (see 8.2 and Appendix VI). Forest users are aware of multiple-products derived from sal forests and they have used them for a long time. Silvicultural regimes therefore need to consider all these types of products. Depending upon the importance of the products, lopping and litter removal regimes should be further developed.

Forest users hold immense knowledge of the use and silvicultural characteristics of many species in sal forests. This research found a good association of ethnicity, gender, income and landholding of the users with indigenous knowledge of plant products and ethnosilviculture. However, the level of association varied according to the status of homogeneity in the users group. With greater heterogeneity in the users group, the poor hold a greater fraction of the knowledge on forest products and ethnosilviculture.

Investigation on indigenous knowledge of forest products and ethnosilviculture resulted in a wide range of products from sal forests and silvicultural information, which are rarely documented. It suggests that forest management planning needs to consider producing products that are important for the users. Such products can only be identified with consultation among all socio-economic groups of the users. Ethnosilvicultural knowledge could be the basis for developing silvicultural regimes for producing products desired by users.

Indigenous knowledge identifies and prioritises forest uses based upon importance and values (of all things in the forest) put by local users. Science could design intervention to improve availability of the desired products. Moreover, experimentation could test the compatibility and complementarity of ethnosilviculture and scientific knowledge, eventually leading to predictability of outcome of certain actions or disturbances. The scientifically derived outcome may enhance indigenous knowledge by providing insights into the changing local situation (Thomson *et al.*, 2000).

Experiments on sal forests may be used to build on and enhance rather than ignoring indigenous knowledge. Indigenous knowledge explored the list of forest products from two sal forests (Appendix VI). The products ranged from locally important fodder (several species are known for different fodder qualities) to exportable products (flower of *Shorea robusta*, and fruits of *Mallotus phillippinsis* are exported to India). For example, different parts of *Phoenix dactylifera* are producing different products ranging from subsistence uses (curry, fruit, rhizome and thatch) to marketable products (fruit and rhizome). Experimentation showed increased regeneration of *Phoenix dactylifera* with increase at 60 and 80% lopping intensity.

Thus, the scientifically derived outcome of increased regeneration of *Phoenix dactylifera* from lopping may improve the production of several products indicated by indigenous knowledge.

The users, particularly key informants, involved since the beginning of research, and also the forestry field staff participated in experimental activities. Based on observation of results in the field, both CFUGs experimented with similar activities in the adjoining block in 1999. These experimental plots were used as demonstration plots during forest management training in the district. Although the final result from the analysis is yet to be communicated and disseminated among all users, most of them have been aware of the things happening in the experimental plots. The research sites have also been visited by other CFUGs of Dang and other districts as part of a forestry study tour. As the treatments were simple and meaningful for subsistence users, the users and forestry field staff are eagerly waiting for results.

The results will be presented to the respective CFUG and forestry staff, and also the results can be verified through field observation. Interaction between users and forestry field staff help empower users with research results. Steps will be initiated to incorporate the research results in operational plans. Presentation of findings in district, regional and national seminars will help incorporate findings in community forestry management manual, and later stage preparing silvicultural guidelines for community forestry. However, it is very important that the distinction between one-event lopping and repeated lopping need to be kept clear. Furthermore, the lopping treatments are to be assessed on its merits or demerits over thinning treatments.

9.3 Research needs

Scientific forest management principles were directed at manipulating forests for timber production or to provide environmental benefits (Wiersom, 1997), and these activities ignored the production of locally important numerous other forest products. Such management, i.e., the mainstream of scientific forest management, did not consider the differential importance and value of forests to different groups of local users. However, growing interests for community forest management increased the need for understanding entire ranges of local users' needs and their way of assessing values for different forest products.

Science and indigenous knowledge can complement each other in community forest management by the involvement of local people (Walker *et al.*, 1999; Thomson *et al.*, 2000). Local communities are extremely knowledgeable about local plants, and such knowledge provides a crucial point to develop scientific forest management (Messerschmidt and Hammett, 1998; DeWalt *et al.*, 1999; Jin *et al.*, 1999). Users of Basanta and Rapti demonstrated their knowledge of various products from sal forests, and also ethnosilvicultural aspects of many species. The knowledge shown by users not only explained about the plants but also expressed importance to their socio-cultural context. *Bauhinia vahlii*, for example, was found very important for the users of both forests, but its regeneration was not recorded in either forest. So any future research efforts to improve the regeneration of *B. vahlii* will be of prime importance to the local users. Thus, indigenous knowledge may form the basis for future research agendas.

The present research, based on the lopping experiments in two sal forests, show the possibility of one-time lopping without adversely affecting stem growth and understory regeneration. The understanding of the physiological responses to lopping of these forests is necessary for general management prescriptions. Such investigations need to cover wider sites, different stages of development, various seasons, and repeated treatments.

Although effects of lopping in one-year following treatment seem promising to both growth of tree and production of leaf-product, the one-year period was not enough from which to draw conclusion about the treatment effects. So a long time-frame research is needed to develop a lopping regime for sal forests.

Few attempts have been made to identify the physiological processes that govern growth responses to pruning, and to develop pruning prescriptions based on observed changes in physiological processes (Singh and Thompson, 1995; Pinkard, 1997). Inadequate information on the appropriate level of pruning intensity and physiological processes has led to conservative pruning prescriptions and practices. Such practices may not reduce the growth on most sites, but may not maximise the clear wood production for a given site, either. More importantly, the conservative pruning may reduce the other potential benefits (e.g., less fodder) from the forests that may be very important specifically for some sectors of the local communities. Furthermore by-products from pruning were least considered in the past. Recently, products of pruning are seen as important while managing the forest for local people. Pruning produces intermediate products for users. But conservative pruning treatments can affect the production of by-products and intermittent products. More comprehensive studies of lopping in multiple-product management are needed.

Forests under the present research showed multi-story structures, and such structures are common in most of the community forests. While practices in both presently studied forests indicate that users are deriving products from all forest layers, little is yet known about the pruning effects on multi-story stands and ground flora, including regeneration. Lopping may promote the growth of understory, and may create avenues for understory regeneration, so lopping effects need to be assessed not only on the basis of effects on tree growth but also on production of other benefits, including by-products.

Litter removal from the forests has rarely been seen as part of forest management, although litter was burnt to encourage regeneration in sal forest (Hole, 1921; Qureshi *et al.*, 1968). Only recently, the practice of litter collection by local people has been recorded and seen as having a negative effect on forest nutrient status (Schmidt *et al.*, 1993; Melkania and Ramnarayan, 1998). But the present research did not record any negative effect on growth or regeneration. However, effects have to be observed for a long time and may depend on the intensity and frequency of litter removal. This has to be examined further.

The silvicultural regime for managing fodder, litter and other NTFPs in a forest has received little attention compared with timber management. But such products are vital for the sustenance of many communities, especially for those residing close to the forests. Management of these products is to be duly considered while managing forests from the local people's perspective.

Usually lopping is done to supply the products for local people, and such products are to be supplied annually. Investigations are to be focused on how the lopping can be regulated in more than one lift, and further investigation on appropriate timing and the severity of a second lift pruning is necessary.

Depending upon the demand and supply situation, sometimes local people may need products from thinning, singling (for small-sized wood), and lopping. Studies (Clark, 1955; Staebler, 1963; LoCho *et al.*, 1997) reported that lopping reduces stem tapering, and this may be very important while producing small-sized wood. There may be some relation among these regimes, and this is worthy of investigation.

Lopping prescriptions are made by comparing its effect on growth with quality improvement of timber (Luckhoff, 1956; Rawat, 1993; Uotila and Mustonen, 1994), rarely considering the importance of certain (lopped) products to local people. Prescribing any lopping or litter-removal regime for community forestry must involve users in order to evaluate the benefits derived from different forest products. Just seeing the stem growth is not enough.

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APPENDIX I: PLANT SPECIES RECORDED DURING FIELD RESEARCH

Code	Local name	Scientific name	Family	Form
1	Sal	*Shorea robusta* Gaertn.	Dipterocarpaceae	tree
2	Bhalayo/kag	*Rhus wallichii* Hook. f.	Anacardiaceae	tree
3	Sindhure/rohini	*Mallotus phillippinensis* (Lam.) Muell.-Arg.	Euphorbiaceae	tree
4	Jamun	*Syzygium cumini*	Myrtaceae	tree
5	Tite	*Clerodendron infortunatum* auct. non L.	Verbenaceae	shrub
6	Boddhairo	*Lagerstroemia parviflora*	Lythraceae	tree
7	Saj	*Terminalia alata* Heyne ex Roth	Combretaceae	tree
8	Dhursimlo	*Colebrookia oppositifolia* Smith	Labiatae	shrub
9	Ankhaartare	*Trichilia connaroides*	Meliaceae	small tree
10	Pepari	*Holoptelea integrifolia*	Ulmaceae	small tree
11	Kadam	*Anthocephalus kadamba*	Rubiaceae	tree
12	Dudhi	*Holarrhenaantidysenterica*	Apocynaceae	small tree
13	Korikath	*Cassine glauca*	Celastraceae	tree
14	Bantindu	*Diospyros montana*	Ebenaceae	tree
15	Karauntikada	*Mariscus sumatrensis* (Retz.) Koyoma	Cyperaceae	small tree
16	Dhairo	*Woodfordia fruticosa* (L.) Kurz	Lythraceae	small tree
17	Kanimauwa	*Glochidion velutinum*	Euphorbiaceae	tree
18	Chukilo/Archal	*Antidesma acidium*	Euphorbiaceae	shrub
19	Bokeno	*Murraya koenigii*	Rutaceae	shrub
20	Gaujo/gurjo	*Tinospora cordifolia*		climber
21	Falamkati	*Homalium nepaulense*	Flacourtiaceae	small tree
22	Mauwa	*Engelhardtia spicata* Leschen. ex Blume	Juglandaceae	tree
23	Badalpate	*Cissampelos pareira*	Menisparmaceae	climber
24	Timila	*Ficus auriculata* Lour.	Moraceae	tree
25	Bakhrigans/kalobilaune	*Reinwardia indica* Dumort.	Linaceae	small tree
26	Tilko	*Hamiltonea sauneoleus* Roxb.	Rubiaceae	small tree
27	Dobare	*Trachelospermum fragrans* (Wallich ex G. Don)	Apocynaceae	climber
28	Tatela	*Oroxylum indicum*	Bignoniaceae	small tree
29	Kukurdiana	*Smilax menispermoidea*	Smilaceae	climber
30	Tendu	*Diospyros malabarica*	Ebenaceae	tree
31	Dubdubbe	*Garuga pinnata*	Burseraceae	tree
32	Pyar	*Buchanania latifolia*	Anacardiaceae	small tree
33	Maainkanda	*Xeromphis spinosa* (Thunb.)	Rubiaceae	small tree
34	Rajbricksha	*Cassia fistula* L.	Caesalpinaceae	tree
35	Koiralo	*Bauhinia variegata* L.	Leguminosae	tree
36	Karma	*Adina cordfolia*	Rubiaceae	tree
37	Pangrang grass			tree
38	Ganeri	*Pieris formosa* (Wallich) D. Don	Ericaceae	small tree
39	Sandan	*Ougeinia oojeinensis*	Papilionaceae	tree
40	Vankapas	*Thespesia lampas* (Cav.) Dalz. & Gibson	Malvaceae	herb
41	Manepat	*Cuauachun cuesicultion*		small tree
42	Charchere	*Tetrastigma dubium*		climber
43	Bhurkoot	*Hymenodictyon excelsum*	Rubiaceae	small tree
44	Balu	*Sida cordifolia* L.	Malvaceae	herb
45	Siris	*Albizia spp.*	Mimosaceae	tree
46	Birale	*Stephania glabra*		climber
47	Bhalayo original	*Semecarpus anacardium*	Anacardiaceae	tree
48	Chuti climber	*Pegia nitida*		climber

Code	Local name	Scientific name	Family	Form
49	Tite tendu	*Diospyros kaki*		tree
50	Kanda	*Randia tetrasperma (Roxb.) Benth. & Hook.f. ex Brandis*	Rubiaceae	small tree
51	Tata/bhorla/maluka	*Bauhinia vahlii Wight & Arn.*	Leguminosae	climber
52	Barro	*Terminalia belerica*	Combretaceae	tree
53	Chhitingri	*Indigofera pulchella Roxb.*	Leguminosae	shrub
54	Noondhiki	*Osyris wightiana*	Santalaceae	climber
55	Lahare grass	*Desmodium spp.*	Leguminosae	climber
56	Siddha	*Anogeissus latifolia*	Dioscoreaceae	tree
57	Baruno	*Stephania spp.*	Menisparmaceae	climber
58	Thakal	*Phoenix dactylifera*	Palmeae	Palm
60	Kattai	*Flacourtia indica*	Flacourtiaceae	tree
61	Manaputale			shrub
62	Bhakhrikane	*Senecio cappa Buch.-Ham. ex D.Don*	Compositae	shrub
63	Kukursuli	*Thalictrum foliolosum DC*	Ranunculaceae	tree
64	Amala	*Phyllanthus emblica L.*	Euphorbiaceae	tree
65	Jhyawali			climber
66	Latimauwa	*Cornus oblonga*	Cornaceae	tree
67	Bamari/debre	*Spatholobus parviflorus*	Leguminoseae	climber
68	Khaltu	*Diospyros melanoxylum*	Ebenaceae	tree
69	Galena	*Sambucus hookeri*	Caprifoliaceae	herb
70	Tite bhate	*Swertia nervosa (G.Don) C. B. Clarke*	Gentianaceae	shrub
71	Bhokate	*Maesa macrophylla (Wallich) A. DC.*	Myrsinaceae	shrub
72	Maidal kande	*Randia dumetorum (Retz.) Lam.*	Rubiaceae	small tree
74	Khosrapatte			shrub
76	Kumbi	*Cochlospermum religiosum*	Cochlospermaceae	tree
77	Fokate jhar	*Flemengia macrophyla*	Leguminosae	shrub
78	Dude lahara	*Trachelospermum lucidum (D.Don) Schumann*	Apocynaceae	climber
79	Budkuro			herb
80	Bire/anukath	*Alangium chinense*	Alangiaceae	small tree
81	Harro	*Terminalia chebula*	Combretaceae	tree
82	Unai lahara	*Lugodium spp.*		climber
83	Satisal	*Dalbergia latifolia*	Leguminosae	tree
84	Pureni	*Cissus javana DC.*	Vitaceae	climber
85	Fhorsa	*Grewia optiva J. R. Drumm. ex Burret*	Tiliaceae	tree
86	Fhorsa pate	*Loucas mollissima Wall.*	Labiataea	herb
87	Sanolati mauwa	*Bassia latifolia*	Sapotaceae	tree
88	Basanta	*Porana grandiflora Wallich*	Convolvulaceae	climber
89	Kusum	*Schleichera trijuga*	Sapindaceae	tree
90	Aruno			climber
92	Gayo	*Bridelia retusa*	Euphorbiaceae	tree
93	Tarul	*Dioscorea spp.*	Dioscoreaceae	climber
94	Siru	*Impereta cylindrica*	Gramineae	grass
95	Muse Jhar	*Capillipedium assimile (Steud.) A.camus*	Gramineae	grass
96	Vhunie Thakal	*Argemone mexicana L.*	Papaveraceae	Palm
97	Jarjare	*Elephantopus scaber*		herb
98	Thulo Bigar Okhati	*Synachium auriculatum*		herb
99	Mahuri Mataune			herb
102	Surkeni Jhar	*Justica simplax*	Acanthaceae	herb
103	Mathe Jhar	*Cyperus rotundus*	Cyperaceae	herb
104	Dhubo	*Cynodon dactylon*	Gramineae	grass
105	Babiyo	*Eulaliopsis binata*		grass

Code	Local name	Scientific name	Family	Form
106	Panch patte	*Orchis incarnata*	Orchidaceae	climber
107	Jiyure saag	*Ophioglossum vurgatum*	Ophioglossaceae	herb
109	Charamilo	*Oxalis corniculata L.*	Oxalidaceae	herb
110	Khari/Khunkhune	*Pogonatheram crinitum*		grass
111	Dopshu/arthunge	*Heteropogon contortus*	Gramineae	grass
112	Bish Khapre	*Sida acuta*	Malvaceae	herb
113	Daddhi	*Eleusine coracana*		grass
114	Chutra	*Carissa erandas*		shrub
116	Jhuse			grass
117	Majeri			herb
118	Pan patte			herb
119	Gol kakri	*Coccinia grandis*	Cucurbitaceae	herb
120	Chhituna kanda/sati bayar	*Rhus parviflora Roxb.*	Anacardiaceae	small tree
121	Maruni/dhagi lahara	*Mardenia celesiana*		climber
122	Biichhad			herb
123	Kanne	*Setaria spp.*		herb
124	Sat aankle	*Hediotes lineata*		herb
125	Khaksi	*Streblus asper*	Urticaceae	tree
126	Khuro	*Cyathula capitata*	Amaranthaceae	herb
127	Tori fulle	*Blumeopsis flava*	Compositae	herb
128	Banso	*Eragrostis tanella*	Gramineae	grass
129	Lahare khuro	*Cynoglossium zeylenicum (Vahl) Thunb. ex-Lehm.*	Boraginaceae	herb
130	Teguna	*Dioscorea bulbifera L.*	Dioscoreaceae	climber
131	Paduli	*Stereospermum spp.*	Bignoniaceae	tree
132	Van Bhesar	*Curcuma aromatica*	Zinziberaceae	herb
134	Kali sinki	*Cheilanthes albomargimata Cl.*		fern
135	Pattke chhau	*Schleroderma spp.*		fungii
138	Furne			fern
139	Hanuman	*Ageratum conyzoides L.*	Compositae	herb
140	Anngari/rudilo	*Pogostemom benghalensis (Burm.f.) Kuntz*	Labiateae	shrub
141	Jharu patte			herb
142	Patel			herb
143	Pyauli jhar	*Trifolium repens L.*	Leguminosae	herb
145	Bhakri			grass
146	Bhui sindure			fern
147	Kanchirni	*Scintapsus officinalis*		climber
148	Lippe kuro	*Desmodium floribundum*	Leguminosae	herb
150	Dapre	*Mazus surculesus*	Araceae	grass
151	Parula		Malvaceae/Bruseaceae	tree
152	Ek sase	*Lantana camara L.*	Verbenaceae	herb
153	Tarul patte /kukurtarul/Liaka	*Dioscorea deltaoide Wallich ex Griseb.*		climber
154	Phusre jhar	*Indigofera spp.*	Leguminosae	herb
155	Yellow flowering kuro			herb
157	Pire grass	*Cymbopogon citratus (DC.) Stap.f.*	Gramineae	grass
159	Dimri	*Zyzyphus xylopyrus*	Rhamnaceae	shrub
160	Shhap			shrub
161	Gurra			grass
162	Charikhuute			grass
163	Bhui lissi			herb
164	Chitre banso	*Arthraxon lancifolius*		grass
165	Bhui grass	*Eriocaulon nepaulensis*	Eriocaulaceae	herb

Code	Local name	Scientific name	Family	Form
167	Bhui khari			grass
168	Bhesar patte /bhui chipi	*Eragrostialla nardoides*	Gramineae	herb
169	Tuki jhar			grass
170	Dhungee marang			herb
171	Ratte jhar	*Anisomeless indica (L.) O. Kuntze*	Labiateae	herb
172	Pattke jhar	*Carpesium nepalense*	Compositae	herb
173	Ban armale	*Anagallis arvensis*	Primulaceae	herb
175	Ankhale jhar	*Chirita urticaefolia Buch.-Ham. ex D.Don*	Cesneriaceae	herb
179	Kose			grass
180	Patlen jhar			shrub
181	Kukhare banso			grass
182	Panyelo pate sinki			fern
183	Kuturke	*Diplazium multicaudatum*	Aspidiaceae	herb
184	Bilaune	*Maesa chisia Buch.-Ham. ex D.Don*	Myrsinaceae	tree
185	Jaru jhar			herb
186	Khar grass	*Arundinella nepalensis*		grass
187	Vhuwa patte lahara			climber
189	Kali Mauwa	*Grewia oppositifolia*		tree
190	Badhar	*Artocarpus lakoocha* Wall. Ex Roxb.	Moraceae	tree
191	Guenlo	*Elaeagnus latifolia*	Elaeagnaceae	tree
192	Khirro	*Sapium insigne (Royle) Benth. ex Hook.f.*	Euphorbiaceae	tree
193	Kalobilaune	*Myrsine semiserrata Wallich*	Myrsinaceae	tree
194	Tolnane/tate	*Dalbergia stipulacea*	Leguminosae	tree
195	Semal	*Bombax ceiba L.*	Bombacaceae	tree
196	Putleto			shrub
197	Bagjunge	*Clematis buchannia DC.*	Ranunculaceae	climber
198	Gaisinge			climber
199	Sano-chameli			climber
200	Bhurunge			climber
201	Chiuri	*Aesandra butyracea (Roxb.) Baehni*	Sapotaceae	tree
202	Phaledo	*Erythrina spp*	Papilionaceae	tree
203	Bagjunge	*Clematis spp*	Ranunculaceae	climber
206	Manakuti/kamalkoti			shrub
207	Thulo-chameli	*Jasminum multiflorum (Burm. f.)*	Oleaceae	climber
208	Sano-dudhi	*Ficus nemoralis*		tree
209	Bhuinkali			shrub
211	Kainyo	*Wendlandia exserta (Roxb.)*	Rubiaceae	grass
212	Kharseti/chhitrachhinki	*Nyctanthus arbor*		grass
213	Banaspati/bhuinsindhur			fern
214	Dhabreghans	*Veronica anagallis L.*	Scrophulariaceae	grass
215	Hale-sadhan			tree
217	Dware/gaitihare	*Inula cappa DC.*	Compositae	shrub
219	Likhate			shrub
220	Sunakhari/katare phul	*Hedychium spp.*	Zingiveraceae	shrub
221	Githa	*Dioscorea spp.*	Dioscoreaceae	climber
222	Kapile			tree
223	Odal/patuwa	*Abroma angustifolia (L.) L.f.*	Sterculiaceae	tree
226	Guhebire			small tree
227	Bori	*Cordia dichotoma*	Cordiaceae	tree
228	Ban-chiura			shrub
229	Malkauna	*Clastrus paniculatus*	Clastraceae	climber
230	Bachha-maruwa			shrub

Code	Local name	Scientific name	Family	Form
231	Lodi	*Symplocos crataegoides Buch.-Ham. ex D.Don*	Symplocaceae	tree
232	Dande	*Xylosma controversum*	Flacourtiaceae	tree
233	Aiselu	*Rubus ellipticus Smith*	Rosaceae	shrub
234	Amriso	*Thysanolaena maaxima (Roxb.) Kuntze*	Gramineae	grass
235	Goldarim			shrub
236	Kanpate	*Sagittaria trifolia L.*	Alismataceae	herb
237	Dholdhole			small tree
238	Khotose			climber
239	Rajukanda	*Ilex dipyrena Wallich*	Aquifoliaceae	tree
240	Dhurro			climber
241	Ail kanda (tharu language)	*Caesalpinia decapetapa (roth) Alston*	Leguminoseae	shurb
242	Amala jhar	*Cassia mimosoides L.*	Leguminoseae	herb
243	Bajra danti /khursani jhar / khareto	*Ludwigia hyssopifolia*	Onagraceae	herb
244	Ban bamari	*Mentha spp.*	Labiateae	tree
245	Banspate	*Rumex dentatus L.*	Tiliaceae	herb
246	Batule jhar	*Stephania japonica*	Menispermaceae	herb
247	Bhuin furseti			herb
248	Budhi kattai			shrub
249	Chheparako makai	*Arthromeris wallichiana*	Polypodaceae	herb
250	Dokhsi			grass
251	Dubi banso			grass
252	Dubi jhar			grass
253	Fulunge /guna puchhere/kutkute/ fulne dari			grass
254	Kalo jhar	*Jusleeia procumbens*		herb
255	Karaunti jhar	*Scleria biflora*		herb
256	Karkyau chyau			fungii
257	Khair	*Acacia catechu*	Legumenaceae	tree
258	Liau jhar			herb
259	Luke jhar	*Galium hirtiflarum*	Rubiaceae	herb
260	Mauti jhar			herb
261	Met	*Holarrhena spp.*	Apocynaceae	small tree
262	Nile fule jhar	*Bluenia spp*		herb
263	Patal kuili			herb
264	Pittamari			shrub
265	Salyau chyau	*Amanita caesama*	Amanitaceae	fungii
266	Sankura ghans			grass
267	Serung ghans			herb
268	Siru pate jhar	*Imperata cylindrica*		grass
270	Tikhe kuro/sinke kuro	*Bidens pilosa*		herb
271	Tin pate / bhatte jhar			herb
272	Tite pati	*Artemisia vulgaris Linn.*	Compositae	shrub
273	Dari-khar			grass
274	Gaijibre	*Sattaria spp*		herb
275	Masino-kuro	*Bidens biternata*	Compositae	herb
276	Ipil-ipil	*Lueceanea spp.*		tree
277	Balaunti	*Psidium gaujava*		tree
278	Sankhula (spiky)			tree
279	Pahele	*Actinodaphne obovata (Nees) Blume*	Lauraceae	tree
280	Tooni	*Toona serrata (Royle) M. Roem.*	Meliaceae	tree
281	Khamari	*Gmelina arborea* Roxb.	Verbenaceae	tree
282	Githi/dar	*Boemeria regulosa* Wedd.	Urticaceae	tree

APPENDIX II: SPECIES RECORDED IN 1997 REGENERATION CENSUS

(Figures in columns 5-7 give the number of quadrats, where species was recorded out of 120 for each site and 240 for total)

Code	Local name	Scientific name	Form	# of quadrats		
				BH	RP	Total
36	Karma	*Adina cordfolia*	tree		4	4
139	Hanuman	*Ageratum conyzoides L.*	herb	63		63
173	Ban armale	*Anagallis arvensis*	herb	5		5
171	Ratte jhar	*Anisomeless indica (L.) O. Kuntze*	herb	5		5
56	Siddha	*Anogeissus latifolia*	tree		1	1
18	Chukilo/Archal	*Antidesma acidium*	shrub	4	3	7
96	Vhunie Thakal	*Argemone mexicana L.*	Palm		97	97
164	Chitre banso	*Arthraxon lancifolius*	grass	27		27
87	Sanolati mauwa	*Bassia latifolia*	tree		4	4
127	Tori fulle	*Blumeopsis flava*	herb	12	3	15
92	Gayo	*Bridelia retusa*	tree		1	1
32	Pyar	*Buchanania latifolia*	small tree	7	8	15
95	Muse Jhar	*Capillipedium assimile (Steud.) A.camus*	grass	4	31	35
114	Chutra	*Carissa erandas*	shrub		18	18
172	Pattke jhar	*Carpesium nepalense*	herb	6		6
34	Rajbricksha	*Cassia fistula L.*	tree		1	1
134	Kali sinki	*Cheilanthes albomargimata Cl.*	fern	92	5	97
175	Ankhale jhar	*Chirita urticaefolia Buch.-Ham. ex D.Don*	herb	3		3
23	Badalpate	*Cissampelos pareira*	climber	8	5	13
84	Pureni	*Cissus javana DC.*	climber		1	1
5	Tite/bhat	*Clerodendron infortunatum auct. non L.*	shrub	26		26
119	Gol kakri	*Coccinia grandis*	herb		3	3
76	Kumbi	*Cochlospermum religiosum*	tree	1		1
8	Dhursimlo	*Colebrookia oppositifolia Smith*	shrub	4	2	6
157	Pire grass	*Combopogon citratus (DC.) Stap.f.*	grass	1		1
126	Khuro	*Cyathula capitata*	herb	1	10	11
104	Dhubo	*Cynodon dactylon*	grass		1	1
129	Lahare khuro	*Cynoglossium zeylenicum (Vahl) Thunb. ex-Lehm.*	herb		1	1
103	Mathe Jhar	*Cyperus rotundus*	herb	22	35	57
83	Satisal	*Dalbergia latifolia*	tree		2	2
148	Lippe kuro	*Desmodium floribundum*	herb	62		62
130	Teguna	*Dioscorea bulbifera L.*	climber		1	1
153	Tarul patte /kukurtarul/Liaka	*Dioscorea deltaoide Wallich ex Griseb.*	climber	5		5
93	Tarul	*Dioscorea spp.*	climber	2	39	41
183	Kuturke	*Diplazium multicaudatum*	herb	1		1
97	Jarjare	*Elephantopus scaber*	herb	15	47	62
113	Daddhi	*Eleusine coracana*	grass		4	4
22	Mauwo	*Engelhardtia spicata Leschen. ex Blume*	tree		1	1
168	Bhesar patte /bhui chipi	*Eragrostialla nardoides*	herb	21		21
128	Banso	*Eragrostis tanella*	grass		8	8
165	Bhui grass	*Eriocaulon nepaulensis*	herb	7		7
105	Babiyo	*Eulaliopsis binata*	grass		2	2
60	Kattai	*Flacourtia indica*	tree	5		5
77	Fokate jhar	*Flemengia macrophyla*	shrub	47	50	97

Code	Local name	Scientific name	Form	# of quadrats		
				BH	RP	Total
31	Dubdubbe	*Garuga pinnata*	tree	1		1
17	Kanimauwa	*Glochidion velutinum*	tree	1		1
189	Kali Mauwa	*Grewia oppositifolia*	tree	3		3
124	Sat aankle	*Hediotes lineata*	herb		18	18
111	Dopshu/arthunge	*Heteropogon contortus*	grass	1	19	20
12	Dudhi	*Holarrhenaantidysenterica*	small tree	1	18	19
10	Pepari	*Holoptelea integrifolia*	small tree	3	4	7
43	Bhurkoot	*Hymenodictyon excelsum*	small tree		6	6
94	Siru	*Impereta cylindrica*	grass	2	51	53
53	Chhitingri	*Indigofera pulchella Roxb.*	shrub	4		4
154	Phusre jhar	*Indigofera spp.*	herb	4		4
102	Surkeni Jhar	*Justica simplax*	herb		77	77
6	Boddhairo	*Lagerstroemia parviflora*	tree	1	34	35
152	Ek sase	*Lantana camara L.*	herb	3		3
184	Bilaune	*Maesa chisia Buch.-Ham. ex D.Don*	tree	2		2
3	Sindhure/rohini	*Mallotus phillippinensis (Lam.) Muell.-Arg.*	tree	7	1	8
121	Maruni	*Mardenia celesiana*	climber	2	3	5
15	Karauntikada	*Mariscus sumatrensis (Retz.) Koyoma*	small tree	3		3
150	Dapre	*Mazus surculesus*	grass	4		4
19	Bokeno	*Murraya koenigii*	shrub	10		10
107	Jiyure saag	*Ophioglossum vurgatum*	herb		5	5
106	Panch patte	*Orchis incarnata*	climber	5	24	29
39	Sandan	*Ougeinia oojeinensis*	tree	1		1
109	Charamilo	*Oxalis corniculata L.*	herb	9	6	15
58	Thakal	*Phoenix dactylifera*	Palm		1	1
64	Amala	*Phyllanthus emblica L.*	tree		2	2
38	Ganeri	*Pieris formosa (Wallich) D. Don*	small tree	2		2
110	Khari/Khunkhune	*Pogonatheram crinitum*	grass	19	1	20
140	Anngari/rudilo	*Pogostemom benghalensis (Burm.f.) Kuntz*	shrub	90		90
88	Basanta	*Porana grandiflora Wallich*	climber		7	7
72	Maidal kande	*Randia dumetorum (Retz.) Lam.*	small tree		18	18
50	Kanda/ Kutkutte kado	*Randia tetrasperma (roxb.) Benth. & Hook.f. ex Brandis*	small tree		5	5
2	Bhalayo/kag	*Rhus wallichii Hook. f.*	tree	1		1
69	Galena	*Sambucus hookeri*	herb		38	38
135	Pattke chhau	*Schleroderma spp.*	fungii		1	1
147	Kanchirni	*Scintapsus officinalis*	climber	9		9
123	Kanne	*Setaria spp.*	herb		6	6
1	Sal	*Shorea robusta Gaertn.*	tree	86	104	190
112	Bish Khapre	*Sida acuta*	herb	1	7	8
44	Balu	*Sida cordifolia*	herb	71	39	110
29	Kukurdiana	*Smilax menispermoidea*	climber	1	4	5
20	Gaujo	*Spatholobus atropuspureus*	climber	5		5
67	Bamari/debre	*Spatholobus parviflorus*	climber		7	7
46	Birale	*Stephania glabra*	climber	1		1
131	Paduli	*Stereospermum spp.*	tree		2	2
125	Khaksi	*Streblus asper*	tree		1	1
70	Tite bhate	*Swertia nervosa (G.Don) C. B. Clarke*	shrub		16	16
98	Thulo Bigar Okhati	*Synachium auriculatum*	herb		1	1
4	Jamun	*Syzygium cumini*	tree	1	1	2
52	Barro	*Terminalia belerica*	tree	2	10	12

Code	Local name	Scientific name	Form	# of quadrats		
				BH	RP	Total
81	Harro	*Terminalia chebula*	tree	1	1	2
7	Saj	*Terminalia alata*	tree		34	34
42	Charchere	*Tetrastigma dubium*	climber	1	2	3
40	Vankapas	*Thespesia lampas (Cav.) Dalz. & Gibson*	herb	1	14	15
78	Dude lahara	*Trachelospermum lucidum (D.Don) Schumann*	climber	1	77	78
9	Ankhaartare	*Trichilia connaroides*	small tree	3		3
143	Pyauli jhar	*Trifolium repens L.*	herb	17		17
16	Dhairo	*Woodfordia fruticosa (L.) Kurz*	small tree	1		1
33	Maainkanda	*Xeromphis spinosa (Thunb.)*	small tree	7		7
61	Manaputale		shrub	3		3
99	Mahuri Mataune		herb		5	5
116	Jhuse		grass		5	5
117	Majeri		herb	1	12	13
118	Pan patte		herb		2	2
122	Biichhad		herb	2	14	16
132	Van Bhesar		herb		13	13
138	Furne		fern		1	1
141	Jharu patte		herb	14		14
142	Patel		herb	11		11
145	Bhakri		grass	5		5
146	Bhui sindure		fern	53		53
151	Parula		tree	1		1
155	Yellow flowering kuro		herb	1		1
160	Shhap		shrub	2		2
161	Gurra		grass	1		1
162	Charikhuute		grass	2		2
163	Bhui lissi		herb	6		6
167	Bhui khari		grass	1		1
169	Tuki jhar		grass	11		11
170	Dhungee marang		herb	4		4
179	Kose		grass	7		7
180	Patlen jhar		shrub	5		5
181	Kukhare banso		grass	4		4
182	Panyelo pate sinki		fern	3		3
187	Vhuwa patte lahara		climber	1		1
		Total count of species		89	74	129

APPENDIX III: ABSENT SPECIES IN 1998

Code	Local name	Scientific name	Form	# count
34	Rajbricksha	*Cassia fistula L.*	tree	1
22	Mauwo	*Engelhardtia spicata Leschen. ex Blume*	tree	1
39	Sandan	*Ougeinia oojeinensis*	tree	1
125	Khaksi	*Streblus asper*	tree	1
155	Yellow flowering kuro		herb	1
167	Bhui khari		grass	1
187	Vhuwa patte lahara		climber	1
83	Satisal	*Dalbergia latifolia*	tree	2
17	Kanimauwa	*Glochidion velutinum*	tree	2
64	Amala	*Phyllanthus emblica L.*	tree	2
162	Charikhuute		grass	2
189	Kali Mauwa		tree	3
181	Kukhare banso	*Verbascum thapsus L.*	grass	4
171	Ratte jhar	*Anisomeless indica (L.) O. Kuntze*	herb	5
170	Dhungee marang		herb	5
182	Panyelo pate sinki		fern	5
150	Dapre	*Mazus surculesus*	grass	6
169	Tuki jhar		grass	7
160	Shhap		shrub	8
165	Bhui grass	*Eriocaulon nepaulensis*	herb	9
142	Patel		herb	10
179	Kose		grass	11
141	Jharu patte		herb	12
124	Sat aankle	*Hediotes lineata*	herb	13

APPENDIX IV: NEW SPECIES RECORDED IN CENSUS 1998

Code	Local name	Scientific name	Form	# count
257	Khair	*Acacia catechu*	tree	1
279	Pahele	*Actinodaphne obovata (Nees) Blume*	tree	1
272	Tite pati	*Artemisia vulgaris Linn.*	shrub	1
249	Chheparako makai	*Arthromeris wallichiana*	herb	1
194	Tolnane/tate	*Dalbergia stipulacea*	tree	1
55	Lahare grass	*Desmodium spp.*	climber	1
68	Khaltu	*Diospyros melanoxylum*	tree	1
86	Fhorsa pate	*Loucas mollissima Wall.*	herb	1
276	Ipil-ipil	*Lueceanea spp.*	tree	1
65	Jhyawali		climber	1
246	Batule jhar		herb	1
248	Budhi kattai		shrub	1
282	Githo	*Boehmeria rugulosa*	tree	2
212	Kharseti/chhitrachhinki	*Nyctanthus arbor*	grass	2
89	Kusum	*Schleichera trijuga*	tree	2
37	Pangrang grass		tree	2
208	Sano-dudhi		tree	2
222	Kapile		tree	2
256	Karkyau chyau		fungii	2
267	Serung ghans		herb	2
119	Gol kakri	*Coccinia grandis*	shrub	3
46	Birale	*Stephania glabra*	climber	3
263	Patal kuili		herb	3
265	Salyau chyau	*Amanita caesama*	fungii	4
199	Sano-chameli		climber	4
25	Bakhrigans/kalobilaune	*Reinwardia indica Dumort.*	small tree	5
247	Bhuin furseti		herb	5
229	Malkauna	*Clastrus paniculatus*	climber	6
261	Met	*Holarrhena spp.*	small tree	6
217	Dware/gaitihare	*Inula cappa DC.*	shrub	6
268	Siru pate jhar		grass	6
275	Masino-kuro		herb	6
66	Latimauwa	*Comus oblonga*	tree	7
260	Mauti jhar		herb	8
266	Sankura ghans		grass	8
253	Fulunge /guna puchhere/kutkute/ fulne dari		grass	9
242	Amala jhar	*Cassia mimosoides L.*	herb	10
250	Dokhsi		grass	11
30	Tendu	*Diospyros malabarica*	tree	12
277	Balaunti	*Psidium gaujava*	tree	13
251	Dubi banso		grass	13
245	Banspate	*Rumex dentatus L.*	herb	14
259	Luke jhar		herb	15
252	Dubi jhar		grass	16
258	Liau jhar		herb	17
262	Nile fule jhar	*Bluenia spp*	herb	18
255	Karaunti jhar	*Scleria biflora*	herb	19
254	Kalo jhar	*Jusleeia procumbens*	herb	20

APPENDIX V: FREQUENCIES BY SITE, YEAR AND SPECIES IN ORDER OF ABUNDANCE

Regeneration frequencies in (from census in 0.012 ha in each site)							
Basanta				Rapti			
1997		1998		1997		1998	
Species	Frequency	Species	Frequency	Species	Frequency	Species	Frequency
139	810	134	2608	102	684	102	745
134	800	146	1428	96	475	116	612
140	599	254	1085	1	395	58	554
146	593	139	847	94	273	1	479
44	284	1	524	78	213	103	462
1	250	148	484	97	209	255	289
148	248	127	461	93	103	118	234
164	105	126	396	77	91	97	210
77	97	164	383	44	89	44	174
5	53	77	201	6	86	106	174
127	48	128	192	103	81	109	174
110	47	262	122	95	76	78	171
143	42	143	94	7	75	127	167
103	39	103	92	69	60	94	163
168	32	258	79	124	49	93	126
141	29	5	71	127	49	95	121
173	23	175	64	70	43	7	109
179	21	161	63	111	39	5	107
97	19	252	62	106	37	107	107
109	18	97	52	122	35	6	98
142	17	110	47	32	34	122	93
163	16	140	43	72	32	77	70
165	16	259	43	52	31	96	70
95	15	245	38	114	22	134	65
160	15	180	34	132	22	128	44
169	12	251	32	40	21	113	43
19	11	106	27	126	21	69	39
23	10	109	24	12	20	138	34
147	10	157	24	117	16	52	32
150	10	23	23	128	15	277	32
33	9	154	21	67	13	30	28
3	8	173	21	109	13	72	28
32	7	152	20	107	12	12	26
106	7	3	15	134	12	98	25
154	7	19	15	112	11	23	24
170	7	112	15	116	11	32	24
171	7	33	14	88	10	250	23
172	7	253	13	18	9	114	22
180	7	8	11	8	8	126	22
182	7	60	10	105	8	40	21
53	6	147	10	123	8	242	21
60	6	260	10	10	7	117	18
61	6	266	10	43	7	88	17
181	6	32	9	99	7	121	15
20	5	111	8	23	6	87	13
126	5	119	8	36	6	132	13
145	5	121	8	50	6	42	12
153	5	18	7	87	6	135	12

Regeneration frequencies in (from census in 0.012 ha in each site)							
Basanta				Rapti			
1997		1998		1997		1998	
Species	Frequency	Species	Frequency	Species	Frequency	Species	Frequency
8	4	20	7	113	5	104	11
9	4	61	7	29	4	111	11
18	4	67	7	104	4	112	11
94	4	113	7	121	4	130	11
112	4	129	7	119	3	139	11
10	3	15	6	131	3	36	10
15	3	42	6	42	2	43	10
93	3	217	6	64	2	119	10
152	3	261	6	83	2	123	10
175	3	268	6	118	2	67	9
183	3	25	5	3	1	84	8
189	3	53	5	4	1	129	8
17	2	172	5	22	1	20	7
38	2	183	5	34	1	29	6
42	2	184	5	56	1	38	6
52	2	247	5	58	1	229	6
117	2	9	4	81	1	275	6
121	2	10	4	84	1	10	5
122	2	38	4	92	1	81	5
157	2	46	4	98	1	50	4
162	2	199	4	110	1	56	4
184	2	16	3	125	1	60	4
2	1	31	3	129	1	66	4
4	1	47	3	130	1	265	4
6	1	66	3	135	1	4	3
12	1	93	3	138	1	105	3
16	1	153	3			120	3
29	1	263	3			161	3
31	1	37	2			163	3
39	1	52	2			3	2
40	1	72	2			18	2
46	1	89	2			31	2
76	1	208	2			33	2
78	1	212	2			70	2
81	1	221	2			92	2
111	1	222	2			99	2
151	1	267	2			131	2
155	1	2	1			168	2
161	1	12	1			256	2
167	1	29	1			9	1
187	1	40	1			65	1
		55	1			68	1
		76	1			86	1
		78	1			110	1
		88	1			194	1
		94	1			248	1
		117	1			249	1
		151	1			257	1
		246	1			276	1
		272	1			279	1

APPENDIX VI: INDIGENOUS KNOWLEDGE OF PLANT PRODUCTS FROM SAL FOREST

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
223	Odal/patuwa	*Abroma angustifolia (L.) L.f.*	Tree	Bark fibre for rope.
36	Karma	*Adina cordfolia*	Tree	Timber, and flowers used in medicine for typhoid.
201	Chiuri	*Aesandra butyracea (Roxb.) Baehni*	Tree	Good fodder, and butter from fruit.
139	Hanuman	*Ageratum conyzoides L.*	Herb	Fodder, and used for compost.
80	Anaukath/bire	*Alangium chinense*	Tree	Small-wood, insect resistant, but susceptible to white-ant; fruit and seed used for fishing-bait and fish-intoxication.
45	Siris	*Albizia spp.*	Tree	Used as timber and fuelwood; cattle like its fodder.
173	Vansamale	*Anagallis arvensis*	Herb	Leaf edible, and tastes good.
56	Siddha	*Anogeissus latifolia*	Tree	Used for small wood (danda-bhata).
11	Kadam	*Anthocephalus kadamba*	Tree	Good timber, fodder, fruit edible; poor people eat the fruit; Tharu (indigenous people in Tarai and inner-Tarai) use it to make poles for carrying load.
18	Amilo	*Antidesma acidium*	Shrub	Good fodder for goat; leaves sour, useful for mixing with leaves of colocasia (taro), used while cooking colocasia leaf curry, fruit also sour and edible.
96	Bhuin/jogini thakal	*Argemone mexicana L.*	Palm	Used for making basket and pot (dhakiya), generates income.
164	Chitrebanso	*Arthraxon lancifolius*	Grass	Good fodder.
190	Badahar	*Artocarpus lakoocha*	Tree	Very good fodder, firewood; fruit tasty and edible by all ages; seed can be sold @ Rs 1 each seed; 2-3 basket (doka) i.e, 100-150 seeds can be collected from a tree.
87	Sanolati Mauwa	*Bassia latifolia*	Tree	Fodder and firewood.
51	Bhorla/maluka/tata	*Bauhinia vahlii Wight & Arn.*	Liana	Bark fibre used for rope i.e., tying livestock (damla), making roofs and beds; leaves used for plates, umbrellas and good fodder; fruit edible, roasted or boiled; root used as medicine with barro (52); fibre (processed or raw) and leaves are very marketble; many people make income from it, can be sold in Bhalubang to snacks seller (chanachutpatte); farm-grown products are not of as good quality as of forest grown ones.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
35	Koiralo	*Bauhinia variegata L.*	Tree	Fodder; flowers edible; young flowers/shoots used for pickle.
127	Torifule	*Blumeopsis flava*	Herb	Flower used in fermenting local liquor.
282	Githo	*Boehmeria rugulosa*	Tree	Good for sickle-holder (khurpeto).
195	Semal	*Bombax ceiba L.*	Tree	Fodder, medicine, and pillows.
92	Gayo	*Bridelia retusa*	Tree	Good fodder, used in firewood too, but explodes.
32	Pyar	*Buchanania latifolia*	Tree	Timber good for yokes; fodder for livestock; firewood; fruits are sweet and sour and ripen in June, eaten by all but mostly by children; used to make local liquor.
95	Muse	*Capillipedium assimile (Steud.) A.camus*	Grass	Good fodder.
114	Chutrakada	*Carissa erandas*	Shrub	Wood used for making tool handles (sickle, spade); also used for firewood; fruit sold @ Rs2 per glass.
34	Rajbrikshya/ bandarlauri	*Cassia fistula L.*	Tree	Wood good for plough; fruits are used for several medicines for clearing urinary tract, cholera, and jaundice; not used for firewood, if burnt chickens will have eye infection.
13	Korikath	*Cassine glauca*	Tree	Fodder for cattle and goats, but not for buffalo; good for timber - good for yokes (juwa) and hair-combs; anecdotally linked with causes for leprosy, so not in use much.
134	Kalisinki	*Cheilanthes albomargimata Cl.*	Fern	Young buds if taken, cure cyst or round worm; helps cure gastric upset; mixed with rock-salt (bire-noon) and herb (juwano) cooked for gastric treatment; pin for making plates or temporary ear-studs; children make impressions (tatoos) from underside of leaves.
175	Aankle	*Chirita urticaefolia Buch.-Ham. ex D.Don*	Herb	Roots used for fermenting; roots can be sold, also good for some infections.
23	Badalpate	*Cissampelos pareira*	Liana	Ground-root mix with water is good medicine for gastric and stomach disorder; special (spiritual) process required to dig rhizome out for treatment; leaves are used to control leaks in copper and bronze water-pots.
84	Purani	*Cissus javana DC.*	Liana	Good fodder for livestock; fruits look like grapes and are edible; all-aged people like fruit; medicine for diarrhea, latex for eye treatment (fulla); fruit can be sold but not much found in forest.
229	Malkauna	*Clastrus paniculatus*	Liana	Fruit controls skin disease; oil is good for scabs.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
197	Bagsinge	*Clematis buchannia DC.*	Liana	Good fodder; root is good for food poisoning.
5	Tite	*Clerodendron infortunatum auct. non L.*	Shrub	Animal bedding; loves good soil and improves soil; medicine for controlling lice in goats; if used for brushing teeth for one year, even bite from poisonous snake has no effect; leaves are medicine for food poisoning; young shoot and foliage are used for skin disease (dad).
119	Golkakri	*Coccinia grandis*	Herb	Fodder; fruits red and sweet, children like fruits; spiritually (Buti) tied around the neck; roots have spiritual value for treatment; root is used spiritually for settling traumatised people (sato-bolaune).
76	Kumbi	*Cochlospermum religiosum*	Tree	Good fodder for cattle, firewood; good for bed posts; stem bark is used for fishing; bark peeled, dried and filled with mud, and used for throwing at wasp-nest (barula ko gola).
8	Dhurseli	*Colebrookia oppositifolia Smith*	Shrub	Good animal bedding, improves forest soil; fodder for goats, foliage is used for banana ripening, as they give off heat; flower is medicine for food poisoning; stem-hairs stop bleeding of fresh wounds.
66	latimauwa	*Comus oblonga*	Tree	Foliage can be used as fodder (only in April-May).
227	Bori	*Cordia dichotoma*	Tree	Young leaves and flowers for curry; specially Tharu use new sprouts for curry; bark is good fibre.
41	Manepat	*Cuauachun cuesicultion*	Tree	Used for ear treatment; used traditionally in wedding ceremony by Tharus.
132	BanVesar	*Curcuma aromatica*	Herb	Rhizome mixed with curd medicine for women's gyno problems; can be sold but FUG hasn't sold so far.
126	Kuro	*Cyathula capitata*	Herb	Cows like when the young plant; cure for partial headache by smelling hands after squeezing leaves; it helps relieve bad infectious mucus if smelt.
104	Dobo	*Cynodon dactylon*	Grass	Oil is extracted from it; fodder.
129	Lahrekuro	*Cynoglossium zeylenicum (Vahl) Thunb. ex-Lehm.*	Herb	Good fodder when young.
103	Mathe	*Cyperus rotundus*	Herb	Good fodder.
83	Satisal	*Dalbergia latifolia*	Tree	Fodder for all domestic animals; good firewood; medicine for typhoid.
148	Lipe	*Desmodium floribundum*	Herb	Fodder.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
130	Teguna	*Dioscorea bulbifera L.*	Liana	Rhizome used for curry/snack; bulb eaten after boiling. Fruits, like (93), are very tasty; leaves good fodder for cattle and goats; fruit has slight sedative effect.
153	Kukur tarul	*Dioscorea deltaoide Wallich ex Griseb.*	Liana	Not edible, but used for medicinal purpose.
93	Tarul	*Dioscorea spp.*	Liana	Leaves fodder; rhizome good for curry; high market potential if collected in substantial amount; sold @ Rs 22/kg; wild (ban-tarul) is smaller than domesticated (ghar-tarul).
221	Githa	*Dioscorea spp.*	Liana	Fruits and rhizome edible.
30	Tendu	*Diospyros malabarica*	Tree	Fruit edible; poor people sell fruit; Rs 1 for 3; wood used for timber.
68	Khaltu	*Diospyros melanoxylum*	Tree	Fodder; leaves popular for cigarettes; fruit edible; fruit is used for treatment in diarrhea, can be used for large-size timber; makes strong stick.
14	Bantendu	*Diospyros montana*	Tree	Fruit edible for humans and monkeys of all ages.
49	Titetindu	*Diospyrus kaki*	Tree	Firewood; can be sold in market; small poles and for some furniture uses.
183	Kuturke	*Diplazium multicaudatum*	Herb	Climber used for tying; fodder good diet for livestock; edible as vegetable in Jun/Jul but later it is used for grass. Used for making jhadu (broom), and can be sold.
191	Guenlo	*Elaeagnus latifolia*	Tree	Fodder but causes dysentery for cattle.
97	Jarjare/ dardare	*Elephantopus scaber*	Herb	Used for local beer; used for yeast (marcha); used for fermenting go fast if its root-ground placed in rice.
113	Daddi	*Eleusine coracana*	Grass	Fodder; used for roofing.
22	Mauwa	*Engelhardtia spicata Leschen. ex Blume*	Tree	Poor quality timber, so not used as much for timber as sal (1) is available; fodder for cattle; flower for local liquor; oil from the seed used by soap factory; oil used for mosquito repellent.
168	Vesharpatte	*Eragrostialla nardoides*	Herb	Grass.; medicine. used for decoration.
128	Banso	*Eragrostis tanella*	Grass	Good grass for all livestock.
165	Bhui	*Eriocaulon nepaulensis*	Herb	Good grass.
202	Faledo	*Erythrina spp*	Tree	Used as stump with spike, then when the cattle scratch their body against the spike, it helps in healing scabs.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
105	Babiyo	*Eulaliopsis binata*	Grass	Used to make rope (damla); broom; roofing of house; sold at Rs 50 per back-load; committee charges two rupees per load.
24	Timila	*Ficus auriculata Lour.*	Tree	Good fodder, increase milk yield; fruit edible by children and also by aged people; leaves used to make plate.
208	Sanodudhi	*Ficus nemoralis*	Tree	Fodder; firewood; fruits are edible.
77	Fokate Jhar	*Flemengia macrophyla*	Shrub	Fodder; using its flower with cow-butter and applying it over the burn can heal the burn wound.
31	Dabdabe	*Garuga pinnata*	Tree	Fodder for all domestic animals; timber, but not very good; firewood but not very good; timber for base of mud-flooring (chirpat); insect resistant; latex for stopping bleeding; bark medicine for dysentery.
17	Kanimwa	*Glochidion velutinum*	Tree	Fodder for goat; used for timber, but not very good.
281	Khamari	*Gmelina arborea* Roxb.	Tree	Fodder; good for musical-drum (madal) and sickle-holder (khurpeto); used in yoke.
189	Kalimauwa	*Grewia oppositifolia*	Tree	Fodder; timber and broom.
85	Forsha	*Grewia optiva J. R. Drumm. ex Burret*	Tree	Good fodder; used as firewood as well; bark fibre for rope (patuwa-damla) and can be sold; poor people make a good living selling rope.
26	Tilko	*Hamiltonea sauneoleus Roxb.*	Tree	Good fodder; red is not palatable but white is palatable; firewood; small-timber does not last even a year; matured timber lasts for four to five years.
124	Sataankle	*Hediotes lineata*	Herb	Fodder for goat, liked by horses too.
220	Sunakhari/katare phul	*Hedychium spp.*	Shrub	Good flower.
111	Dapsu	*Heteropogon contortus*	Grass	Used for roofing; fodder for cattle and buffalo; used for roofing.
12	Dudhi	*Holarrhenaantidysenterica*	Tree	Goats like it, cattle do not prefer it; good for butter-churn (madani); blacksmith (Kami) make sickle-holder (khurpeta); insect resistant; medicine for stomach and typhoid, but mostly used by poor people; stem bark is fed when worms are in stomach; fruit is mixed with *Prunus persica* (aru) and is good for intestinal problems.
10	Pepari	*Holoptelea integrifolia*	Tree	Fruits are used for fishing (intoxication).

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
43	bhurkoot	*Hymenodictyon excelsum*	Tree	Fruit inedible, seeds are sweet; small wood (danda-bhata).
239	Rajkanda	*Ilex dipyrena Wallich*	Tree	Used for small wood (dhata-bhata).
94	Siru	*Impereta cylindrica*	Grass	Filtrate of ground root, mixed with water, is fed to calfs for worm-treatment; Tharu make brooms; fodder; also used for roofing.
53	Sagina	*Indigofera pulchella Roxb.*	Shrub	Fodder for all domestic animals; flower good for pickle and curry.
154	Fushre	*Indigofera spp.*	Herb	Fodder.
217	Dware/gaitiha re	*Inula cappa DC.*	Shrub	Leaves for liquor; flowers for decoration.
207	Thulochameli	*Jasminum multiflorum (Burm. f.)*	Liana	Fodder.
102	Surkane	*Justica simplax*	Herb	Small herb; good fodder.
6	Baidar	*Lagerstroemia parviflora*	Tree	Good fodder during January; resin is popular like chewing gum; children eat resin; good small timber but lasts only two years; timber for implement handles; susceptible to insect.
152	Eksase	*Lantana camara L.*	Herb	Firewood.
86	Forsapate	*Loucas mollissima Wall.*	Tree	Flower black, edible by all ages.; can be collected in large amounts and possibilities for marketing.
82	Unailahra	*Lugodium spp.*	Liana	Animal bedding and compost.
3	Sindhure	*Mallotus phillippinensis (Lam.) Muell.-Arg.*	Tree	Fruit is traded in India but not locally; root powder medicine for gastric problem; used in small wood (bhata); good fodder; fruit + shoot of *Porana grandiflor (a*akase beli) for animal cholera; fruit for dysentery; fruit is medicine for cattle joint and intestine disorder, it is fed by grinding; syrup extract for sore intestine (gano).
121	Dhagi/ Maruni	*Mardenia celesiana*	Liana	Thread from core of stem is used to make rope for fishing rod; fodder for goat.
15	Karaunitikanda/ chutrakanda	*Mariscus sumatrensis (Retz.) Koyoma*	Tree	Fruit sweet edible and used for local liquor; fruit medicine for diarrhea, and constipation; good fodder, but not for cow; stem used for fencing.
150	Dapre	*Mazus surculesus*	Grass	Fodder.
244	Kali/ban bamari	*Mentha spp.*	Tree	Good fodder.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
19	Bakeno	*Murraya koenigii*	Shrub	Leaves good in dal (bean-soup); and for curry dressing; used to kill bugs; leaves are to bedded for poultry if they are with lice (sulsule); fruit is black when ripe and eaten by children; fruit for medicine; timber is hard.
212	Kharseti/chhit rachhinki	*Nyctanthus arbor*	Grass	Fodder.
107	Jiuresag	*Ophioglossum vurgatum*	Herb	Good vegetable; nutritious; poor people use in curry for domestic use, one kg enough curry for 1 family; medicine; can be sold but not much in production.
106	Panchpate	*Orchis incarnata*	Liana	Fodder for goat; root is used for treating food poisoning; ground-root expells placenta after birth.
28	Tatela	*Oroxylum indicum*	Tree	Fruit also edible for cattle; fodder good for cattle; fruit-bark are good medicine for burnt skin.
54	Noondhiki	*Osyris wightiana*	Liana	Medicinal use.
39	Sadan	*Ougeinia oojeinensis*	Tree	Flower is bitter in taste; eaten as pickle; wood good for plough, beds' legs, also as fodder; good timber. root also used for making ploughs.
109	Charamilo	*Oxalis corniculata L.*	Herb	Sour in taste; used in bean-soup (dal); cattle and buffalo like it; if added in curry of tubers it gives good flavours; medicine for eye.
48	Chutilahra	*Pegia nitida*	Liana	Fodder.
58	Thakal	*Phoenix dactylifera*	Palm	Bear likes fruit best; porcupine likes rhizome and root; cowboys collect rhizome, edible as curry; two to four rhizomes are enough for one's meal; can also be sold; fruit (khajur) edible and saleable ; children sell fruit; fruits are sold at Rs 5 per leaf-plate (tapari) or @ Rs 2.00 per glass; leaves used for roofing of house instead of thatch; leading shoot is eaten.
64	Amala	*Phyllanthus emblica L.*	Tree	Fruit edible allover, and saleable @ Rs 4 per kg; but not many trees, so no traders; Tharu people look for its fruit a lot; .used as medicine for skin disease; firewood contaminates wine; not used as firewood for it causes chicken' s eye infection.
38	Gaineri	*Pieris formosa (Wallich) D. Don*	Tree	Fodder; used for firewood too; bark used as medicine for blood-dysentery (ragatmasi); ground bark mixed with water is filtered and drunk; bark used as medicine for headache, fever and hotness; one with thorn is medicinal.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
110	Kharighas	*Pogonatheram crinitum*	Grass	Pin for making leaf plate; fodder for all.
110	Khunkhune	*Pogonatheram crinitum*	Grass	Medicine, ground applied for lower abdomen pain.
140	Angeri	*Pogostemom benghalensis (Burm.f.) Kuntz*	Tree	Fodder; firewood; good timber, but small in size; new flush is poisonous.
88	Basanta	*Porana grandiflora Wallich*	Liana	Fodder for livestock.
72	Maidlkada	*Randia dumetorum (Retz.) Lam.*	Tree	Spike very poisonous; fruit used for fishing; bark mixed with bark of dudhi (12) and bamari (67), and 7 new shoots of tite (5) makes medicine for typhoid.
50	Kutkutekando	*Randia tetrasperma (Roxb.) Benth. & Hook.f. ex Brandis*	Tree	Timber too hard to chop; fruit core (guvo) used as soap in old days; fruit cures some diseases of heart and lungs.
120	Chhitauni	*Rhus parviflora Roxb.*	Tree	Fodder for goat; firewood; legs for furniture; used for fencing.
2	Kag-Bhalayo	*Rhus wallichii Hook. f.*	Tree	Good fodder; good for yokes; ripened fruits good for stomach pain; allergen for some people; good for decoration in festivals; fruits protect from witches; plough made of this wood makes the land fertile; firewood sparks.
233	Aiselu	*Rubus ellipticus Smith*	Shrub	Preferred fruit.
236	Kanpate	*Sagittaria trifolia L.*	Herb	Good for ear infection.
69	Galena	*Sambucus hookeri*	Herb	Fodder; used to treat boils, and eyes treatment (andha).
192	Khirro	*Sapium insigne (Royle) Benth. ex Hook.f.*	Tree	Green manure, and works as insecticide.
89	Kusum	*Schleichera trijuga*	Tree	Timber is tough; used for plough; good for chopping board; fodder for all; firewood; fruit is green with inner portion yellow and tastes sour liked by all age group; poor people pick the fruits from the tree; possibilities of selling fruit.
135	Patkechyau	*Schleroderma spp.*	Fungi	Curry food; collected from the jungle for curry; Rs 20-30 per kg can be sold.
147	Kansirni	*Scintapsus officinalis*	Liana	Sap is used as gum.
255	Karauntijhar	*Scleria biflora*	Herb	Plant used for gastric problems.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
47	Bhalayo	*Semecarpus anacardium*	Tree	Fruit sweet and edible for some persons, but is allergen too for some people; fruit red when ripe liked by children; seed very tasteful; latex is poisonous and allergen for some persons; seed oil poisonous for skin; spiritual use (Buti) for newly born animals in traditional way in Pyuthan; leaves are put in house; application on broken skin and cuts helps healing.
145	Bhakri ghas	*Senecio cappa Buch.-Ham. Ex.D.Don*	Grass	Fodder for goat.
123	Kane	*Setaria spp.*	Herb	Good curry; squeeze and apply the drops in ear in time of infection; Pig like leaves; leaves plucked and mixed with Besan (ground of chick-peas) to make cutlets (Pakauda).
1	Sal	*Shorea robusta Gaertn.*	Tree	Good fodder; root is good firewood; curd + latex used as medicine for dysentery; mixing bark of mango, sal, amla (64) and harro (81) trees makes a medicine; juice from ground fruit of sal, harro and barro (52) is good for gastric problems; latex mixed with edible oil has aromatic use; bark extract is used for preserving and decorating sawn wood ; young trees can be used in splinters; best timber; good for dehusking implement (dhiki); when water of old sal tree (Female ?) is drunk the women will have regularperiods ; west-facing old tree is selected, outer epidermis of east face is scraped, and inner epiderm is collected, ground to powder then applied to cuts or wounds; still in use today; leaves are used to make plates; leaves can be used for cigarettes; seeds are eaten by cattle and goats but not by birds; seeds used to be used in traditional wine making; oil from sal seed is good for intestinal problems; flowers are traded from Nepalgunj to India for medicine.
112	Biskhapre	*Sida acuta*	Herb	Ground leaf helps to heal broken legs and other wounds of animals; leaf used widely as medicine.
44	Balu	*Sida cordifolia*	Herb	Stem sometimes used to make the local liquor strong; used to squeeze boil; leaves are good medicine; used in fodder when young; brooms; used for rope; used as catalyst with Mauwa (22) for fermenting.
29	Kukurdain	*Smilax menispermoidea*	Liana	Leaf for goats and cows; young foliage used for curry; medicine for warts; flower is good for pickles.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
67	Bamari	*Spatholobus parviflorus*	Liana	Good fodder; medicine for food poisoning; bark used as medicine for typhoid; fruit over-proteinous.
46	Birale	*Stephania glabra*	Liana	String to tie up grass loads; good fodder for goats; temporary fencing; rhizome good for gastric and other intestinal problems; stem fed to make livestock conceive.
57	Baruno	*Stephania spp.*	Liana	Good for fodder, also fuelwood; flowers for festivals.
131	Paduli	*Stereospermum spp.*	Tree	Good fodder; firewood; tough wood.
125	Khaksi/Sitasinki	***Streblus asper***	Tree	Fodder; firewood; ornamental plant; flower use in puja (relgious ceremonies); used for yeast (marcha).
231	Lodi	*Symplocos crataegoides Buch.-Ham. ex D.Don*	Tree	Bark was trade 50-60 years ago @ Rs 0.04 /dharni (2.4 kg), but not any more; dry bark sold in Bahadurgunj (Krishna Nagar); tree bark good for eye infection.
4	Jamun	*Syzygium cumini*	Tree	Good for timber; bark-ash good for teeth-gum disease; fruit edible; fruits used for making local liquor; poor people are involved in trade of its fruit; fruit can be used for other medicine from the fruit; stomach medicine; about 100 litres (a muri) can be collected.; Rs 10-20 per litre (Rs 5-10 per mana); Rs 2 per glass.
52	Barro	*Terminalia belerica*	Tree	Fruit skin + maluka's (51) root + dimri's (159) root +badelpate's (23) root + dhairo's (16) bark + mango bark skin + sal's bark + black turmeric + turmeric. All this mixture when dried and ground to powder serves as medicine for gastric problems; very good fodder; good timber; fruit edible, if taken by children causes them to choke.
81	Harro	*Terminalia chebula*	Tree	Fodder; used with Barro (52) for medicinal purpose; timber useful; fruit dipped in urine of cow, then roasted and eaten is good for cough; bark used to make permanent ink.
7	Saj	*Terminalia tomentosa*	Tree	Used as timber instead of sal; hard timber, long-lasting inside; firewood; bark-ash gives lime colour, use for paint; good fodder, and particularly very important during winter.
42	Charchare	*Tetrastigma dubium*	Liana	Fodder for cow, no fruiting; used to tie thatch.
63	Kukursuli	*Thalictrum foliolosum DC*	Tree	Animal bedding; wood is good for ploughs; medicine.
40	Vankapas	*Thespesia lampas (Cav.) Dalz. & Gibson*	Herb	Can be used as cotton but in a small amounts; fodder for all domestic animals but not preferred.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
234	Amriso	*Thysanolaena maaxima (Roxb.) Kuntze*	Grass	Broom and thatch.
20	Gaujo	*Tinospora cordifolia*	Liana	Good fodder; leaves good for treating goats and other anumal lice; root is good for treating worms in goats.
78	Dudelahara	*Trachelospermum lucidum (D.Don) Schumann*	Liana	Fodder for goats.
9	Ankhatare	*Trichilia connaroides*	Tree	Fodder; firewood; small wood (danda-bhata and chirpat); useful for timber; insect resistant.
143	Payauli jhar	*Trifolium repens L.*	Herb	Fodder.; children eat flowers.
181	Kukhure	*Verbascum thapsus L.*	Grass	Grass; increases lactogen in animals; used for roofing.
214	Dabre	*Veronica anagallis L.*	Grass	Flower, leaf used for fermenting; decorative.
211	Kainyo	*Wendlandia exserta (Roxb.)*	Grass	Fodder.
16	Dhairo	*Woodfordia fruticosa (L.) Kurz*	Tree	Fodder for all animals; bears like flowers, and also by children; children like nectar; fruit not in use so far; stem bark is used to control diarrhea in April-May; ground dried-flower medicine for dysentery; long-lasting pegs for animal sheds.
33	Mainkada	*Xeromphis spinosa (Thunb.)*	Tree	Leaves fodder for goats; used for fishing- intoxicating.
232	Dande	*Xylosma controversum*	Tree	Good fodder; young foliage makes good curry in May/June.
159	Damrai	*Zyzyphus xylopyrus*	Tree	Fruit; fodder.
37	Pangrang		Tree	Fodder and fuelwood.
61	Manputali		Shrub	Fodder for all; firewood; children suck flower-nectar, as it tastes very good.
65	Jawali		Liana	Fodder for goat.
74	Khosra pate		Shrub	Fodder, fruit edible.
79	Budkuro		Herb	Grass.
99	MauriMataune jhar		Herb	Chewed root is blown at bees, to keep them away, and so honey can be harvested; its leaf gives off a bad smell.
116	Jhuse		Grass	Fodder for all.
117	Majheri		Herb	If root's juice taken, it helps for common illnesses; used as yeast for fermenting.
118	Panpate		Herb	Goats like this fodder.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
122	Bichhad		Herb	Story goes - cut and boil bulb and place it in position saying that you will be coming after a week, but in fact you come on the sixth day and take it, that way it won't have any poison; tastes good, and good food, otherwise if you come on the seventh day it is poisonous; helps heal scratches made by leopards (chitwa).
138	Furne		Fern	Frequently used for medicinal purposes; latex applied over the infected surface, serves as good medicine.
142	Patal		Herb	Fodder; dried and its smoke is good for health.
146	Vuisindhur		Fern	Fodder for cows in rainy season; used in religious events.
151	Parula		Tree	Fodder; firewood.
161	Gura		Grass	Roofing, fodder and also for fertilizer.
162	Charikhutte		Grass	Grass.
167	Bhuikhari		Grass	Fodder.
169	Tukijhar		Grass	Fodder.
170	Dhungemarying		Herb	Medicine.
179	Koshe		Grass	Grass.
180	Patlane		Shrub	Fodder.
188	Aaugari/rudilo		Herb	Medicinal use.
196	Putleto		Shrub	Can be used to make clothes (Bhangra).
198	Gaisinge		Liana	Good fodder.
199	Sanochameli		Liana	Good fodder.
209	Bhuinkali		Shrub	Fodder.
213	Banaspati/bhu insindhur		Fern	Fodder.
215	Halesadan		Tree	Used to make ploughs.
219	Likhate		Shrub	Fodder.
222	Kapile		Tree	Fodder and timber.
226	Guhebire		Tree	Fodder favoured by goats; medicine for food poisoning and dental treatment.
228	Ban-chiura		Shrub	Children eat fruit.

Code	Local name	Scientific name	Form	Statement (number/s in brackets are spp code)
230	Bachha-maruwa		Shrub	Poor fodder; root used as spiritual potion (buti) for newly born child or animal if the previous child has not survived. Root fed to cows.
237	Dholdhole		Tree	Medicinal use.
238	Khotose		Liana	Fodder.
240	Dhurro		Liana	Good fodder for goats, latex applied for sore throat.

APPENDIX VII: ETHNOSILVICULTURAL INFORMATION

Code	Local name	Scientific name	Form	Statement (number/s in bracket denote spp.code)
139	Hanuman	*Ageratum conyzoides L.*	Herb	Very short life span, white flower.
80	Anaukath/bire	*Alangium chinense*	Tree	Associate of sal in moist area; does not damage sal but not much left now; flowering in Apri-May, fruiting in June; fruit bursts when ripe, and fruit contains many seeds.
45	Siris	*Albizia spp.*	Tree	Mixed with sal and saj (7) but in low density.
56	Siddha/jogini dairo	*Anogeissus latifolia*	Tree	Flowers are white, and flowering in April.
18	Chukilo	*Antidesma acidium*	Shrub	Grows in hill and plain, also in dry location; up to 4 m tall; flowering in winter (Oct- Feb), fruit ripens in Dec-April; fruits are in bunches, and one seed per fruit.
96	Bhuinthakal	*Argemone mexicana L.*	Palm	Spreads on ground; wider leaves than of thakal (58).
35	Koiralo	*Bauhinia variegata L.*	Tree	Only found in higher part of sal forests.
127	Torifule	*Blumeopsis flava*	Herb	Germinates in Jun/Jul and dies Dec/Jan.
92	Gayo	*Bridelia retusa*	Tree	Available in fringes of sal forest, by the side of farm.
32	Pyar	*Buchanania latifolia*	Tree	Flowers in April/May, fruit ripens in June; seed dispersal by bear and bird.
95	Musejhar	*Capillipedium assimile (Steud.) A.camus*	Grass	Grows in wet part of sal forest, and in shade.
34	Rajbrisya	*Cassia fistula L.*	Tree	Grows with rohini (3) and sal.
13	Korikath	*Cassine glauca*	Tree	Propagates from seed; grows tall; found everywhere; increasing in number; dispersed widely and far too; flowering in May-June; flowers red; fruits yellow in bunch in Nov-Dec, falls in Jan; sheds leaves in Apr-May.
134	Kalisinki	*Cheilanthes albomargimata Cl.*	Fern	Found by the side of river in damp place.
23	Badalpate	*Cissampelos pareira*	Liana	Grows in sunny areas; sprouts in May/June and dries (leaf shedding) in Mar, flowering in Apr/May.
84	Purani	*Cissus javana DC.*	Liana	Abundant in wet land rather than in dry; annual herb found in valley like lowland rather than in hill; dies in Jan and sprouts in rainy season. Another variety (Thulo-pureni) has leaf like that of grape and is not fodder.
229	Malkauna	*Clastrus paniculatus*	Liana	Tangles in big tree; flowering in Apr/May; fruits in bunch and burst when ripe.

Code	Local name	Scientific name	Form	Statement (number/s in bracket denote spp.code)
203	Bagjunge	*Clematis spp*	Liana	Flowering in Dec.
5	Tite	*Clerodendron infortunatum auct. non L.*	Shrub	Grows in moist area; not in hills; grows up to 1.5 m tall; propagates from root, flowers red, flowering after leaf shedding in Mar/Apr; fruiting in Apr; fruits like finger but smaller; fruits are eaten by birds.
119	Golkakri	*Coccinia grandis*	Herb	Rare these days.
76	Kumbi	*Cochlospermum religiosum*	Tree	Distributed in high land, but not widely; propagates from seed, flowering in Apr/May; deer like flowers; fruits slightly larger than pears.
126	Kuro	*Cyathula capitata*	Herb	It is in dry locality.
83	Satisal	*Dalbergia latifolia*	Tree	Found in all ranges, but in fertile soil.
130	Teguna	*Dioscorea bulbifera L.*	Liana	Found in large amounts.
93	Tarul	*Dioscorea spp.*	Liana	Annual herb found in shade with sal; was plentiful in the past, but it is rare now.
30	Tendu	*Diospyros malabarica*	Tree	Fruit ripens in Jun/Jul.
68	Khaltu	*Diospyros melanoxylum*	Tree	Fruit ripens May/Jun.
191	Guenlo	*Elaeagnus latifolia*	Tree	Flowers in bunches.
97	Jarjarejhar	*Elephantopus scaber*	Herb	Found in wet place or shade of sal forest.
113	Daddi	*Eleusine coracana*	Grass	Not many; abundant in dry area mixed with khar (186).
22	Mauwa	*Engelhardtia spicata Leschen. ex Blume*	Tree	Giant tree; associate of sal; but only a few left in the forest; not in high altitude; flowering Apr/May; flower falls to the ground after fertilization; flower collected from ground in May/Jun.
128	Banso	*Eragrostis tanella*	Grass	Found in forest in rainy season.
105	Babiyo	*Eulaliopsis binata*	Grass	Found where sal is not found in plain area.
24	Timila	*Ficus auriculata Lour.*	Tree	Associate of sal; mostly in moist area and depressions.
60	Kattai	*Flacourtia indica*	Tree	Has prickly spikes; many trees; fruit ripens in May/Jun; fruits in bunches and are edible; birds and bears like fruits.
77	Fokke	*Flemengia macrophyla*	Shrub	Found in high land by the side of the river.
31	Dabdabe	*Garuga pinnata*	Tree	In moist site; sometimes in middle of sal forest; sheds leaves early and sprouts last in the season.
189	Kalimauwa	*Grewia oppositifolia*	Tree	Many in the forest with sal in highland.
85	Forsha	*Grewia optiva J. R. Drumm. ex Burret*	Tree	Rare in jungle; found in sunny area.

Code	Local name	Scientific name	Form	Statement (number/s in bracket denote spp.code)
26	Tilko	*Hamiltonea sauneoleus Roxb.*	Tree	Two types - red and white; small tree in low altitude; red smaller leaf and is useful; white grows bigger, and has round leaf.
124	Sataankle	*Hediotes lineata*	Herb	Found in damp and fertile place.
12	Dudhi	*Holarrhenaantidysenterica*	Tree	Only on the plains, not on slopes; flowers annually in Mar/Apr just after leaf shedding; fruits are fine, not seen much.
10	Pepari	*Holoptelea integrifolia*	Tree	Grows in depressions and ridges, but more in moist parts; grows to tall tree; flowering annually in Apr/May; sheds leaves when it starts flowering; flowers yellow and fruit red; seeds are granular inside the fruits; birds disperse seeds.
94	Siru	*Impereta cylindrica*	Grass	Found in dry place by itself mostly.
53	Sagina	*Indigofera pulchella Roxb.*	Shrub	Two types - small and big one; grows in sal forest and specifically in boulder soil; flowering in Apr/May; flowers blue; people and birds favour ripe fruits.
6	Baidar	*Lagerstroemia parviflora*	Tree	Germinates from seed; giant size trees in drier sites; trees becoming more plentiful; flowering in Apr/May; fruiting in May/Jun; seeds small slightly bigger than maize, surrounded by prickles; seeds are heavy.
86	Forsapate	*Loucas mollissima Wall.*	Tree	Found in spacious places in hills.
3	Sindhure	*Mallotus phillippinensis (Lam.) Muell.-Arg.*	Tree	Associate of dry sal; mostly in dry unfertile land with other species; flowering in Jan; fruiting in late Jan; red fruit; birds disperse the seed; sheds leaves in Feb.
121	Maruni	*Mardenia celesiana*	Liana	Tangled in sal trees in damp area; germinates in May/Jun and dries in Mar/Apr.
15	Karaunitikanda/chutrakanda	*Mariscus sumatrensis (Retz.) Koyoma*	Tree	Flowering in Mar/Apr.
19	Bakeno	*Murraya koenigii*	Shrub	Flowering in Mar/Apr; fruit ripens in Apr/May; seeds are large and black.
107	Jiuresag	*Ophioglossum vurgatum*	Herb	Found around sal in plain and highland areas where no other herbs stand; large numbers during rainy season; flowers and fruits from guvo (leading shoot).
106	Panchpate	*Orchis incarnata*	Liana	Tangled with trees in highlands; germinates in May/Jun and dries out in Dec/Jan; fruit ripens in Jul/Aug.

Code	Local name	Scientific name	Form	Statement (number/s in bracket denote spp.code)
28	Tatela	*Oroxylum indicum*	Tree	Not many in forest; available in high or low altitudes; grows to big tree, but banana-like stem; flowering in Oct and fruits ripen in Jan; fruits are long and look like sword; many seeds in a fruit.
39	Sadan	*Ougeinia oojeinensis*	Tree	Mixes with koiralo (35); found in highland.
109	Charmilo	*Oxalis corniculata L.*	Herb	Found in large numbers, less on slopes; grows better in wet areas.
48	Chutilahra	*Pegia nitida*	Liana	Mixes very well with other fodder, mostly on river-sides.
58	Thakal	*Phoenix dactylifera*	Palm	Fruit ripens in Jun/Jul; bears come around; rhizome matures in month of Jun/Jul; porcupines dig holes for rhizome and root.
64	Amala	*Phyllanthus emblica L.*	Tree	Flowering in Jun/Jul.
38	Ganeri	*Pieris formosa (Wallich) D. Don*	Tree	Two types; rare in forest these days; found with other good fodder in highlands; grows better in wet place.
110	Khunkhune	*Pogonatheram crinitum*	Grass	Found in shade and wet area.
88	Basanta	*Porana grandiflora Wallich*	Liana	Found almost anywhere; flowering in rainy season; flower white and perfumed; fruits are black like chutra (114); fruits are eaten by birds and wild chicken; propagates from seed only dropped by birds.
50	Kutkute	*Randia tetrasperma (Roxb.) Benth. & Hook.f. ex Brandis*	Tree	Common; thorny, good wood when it is big; white fruiting like that of bel (*Aegle marmelos*).
2	Kag-bhalayo	*Rhus wallichii Hook. f.*	Tree	Grows in dry and sunny sites in higher altitude; also few in dry sites on the plain; site specific, found only on the cliff; not extending beyond the existing sites; no other plants around; not many in number; grows to the size of a plough; flowers annually in May.
69	Galena	*Sambucus hookeri*	Herb	Annual herb seen around Apr/May; grows in moist area; flowering in rainy season (Jul/Aug) and fruits; does not hold leaves in winter; has male and female plants - long bulb male and short one is reckoned to be female.
89	Kusum	*Schleichera trijuga*	Tree	Found mainly on the plain with sal; sal (1) saj (7) and barro (52) accompany it in the highland.
135	Patkechyau	*Schleroderma spp.*	Fungi	Found only in Jun/Jul.
147	Kansirni	*Scintapsus officinalis*	Liana	Tangles tightly with tree.
255	Karauntijhar	*Scleria biflora*	Herb	Looks like sharp edge of saw (karaunti).

Code	Local name	Scientific name	Form	Statement (number/s in bracket denote spp.code)
47	Bhalayo	*Semecarpus anacardium*	Tree	Small tree, abundant in dry-slopes; flowering in July-Aug; fruit ripens in Nov-Dec.
1	Sal	*Shorea robusta Gaertn.*	Tree	Protected only, propagated from seed and root-sucker but not transplanted; flowering in Feb/Mar; flowering every year but heavy alternate year; fruiting in Apr/May; seed remains on tree till mid-May; seed falls in May; seeds fall under the tree, do not go far; leaves shed after Mar; profuse regeneration in the ground just after seed fall, but no further growth; grazing has resulted in the lack of seedlings; Sal, saj(7) amp (mango) flower at the same time.
112	Biskhapre	*Sida acuta*	Herb	Observed in Apr/May in damp area.
29	Kukurdaina	*Smilax menispermoidea*	Liana	Plenty; flowering in Apr and fruiting immediately; fruits in bunch like pureni (84), red fruit.
67	Bamari	*Spatholobus parviflorus*	Liana	Grows many years (20-25 years); should not be lopped while it is growing; to be lopped just before leaf shedding; when fruits fall to the ground, they germinate; can be transplanted, and fodder can be collected after 10 years; propagates from rhizome, too.
46	Birale	*Stephania glabra*	Liana	Damages sal tree (tangled); found in highland; leaves are long like of bamari (67), and fully developed in August; sheds leaves by Nov; propagates from rhizome.
57	Baruno	*Stephania spp.*	Liana	Flowering in Dec/Jan; continuous flowering and leaf shedding, never is naked; grows mostly in wet area.
131	Paduli	*Stereospermum spp.*	Tree	Found mixed with sal; flowering in rainy season (Jul-Aug); fruits look like a cultivated fruit tree (sittal-chini).
125	Khaksi	*Streblus asper*	Tree	Grows in landslide soil.
4	Jamun	*Syzygium cumini*	Tree	Grows in moist area on plain and hills, more on river- sides; increasing numbers; flowering annual in Apr/May; seeds are fine and ripen in May/Jun/Jul; birds disperse seeds.
7	Saj	*Terminalia tomentosa*	Tree	Grows in dry and wet areas; flowering in Apr/May; fruit breaks after rain; fruit is large but seeds are small; 10-12 seeds per fruit.
42	Charchare	*Tetrastigma dubium*	Liana	Propagates from root; tangles sal trees but no damage.
63	Kukursuli/tite	*Thalictrum foliolosum DC*	Tree	Big deciduous tree.
40	Vankapas	*Thespesia lampas (Cav.) Dalz. & Gibson*	Herb	Found in jungle with sal (1) and saj (7); grows to 2 m high; fruit blows like cotton and matures in Dec.

Code	Local name	Scientific name	Form	Statement (number/s in bracket denote spp.code)
20	Gaujo	*Tinospora cordifolia*	Liana	Mostly in depressions in isolation or twisting large tree; seems like tree; fruit like bean.
78	Dudelahara	*Trachelospermum lucidum (D.Don) Schumann*	Liana	Spoils tree; fruits are fine and blown by wind; sprouts leaves immediately after leaf shedding.
9	Ankhatare	*Trichilia connaroides*	Tree	Grows to big tree, seems to propagate from root; leaf shedding in Feb/Mar; flowering in Apr/May after leaf shedding; fine flowers and fruits.
143	Payauli jhar	*Trifolium repens L.*	Herb	Found in damp area with sal.
16	Dhairo	*Woodfordia fruticosa (L.) Kurz*	Tree	Colonizes landslide sites, sunny area and dryland; pure patch; regenerates on abandoned land, which is normally dry and lack s nutrient; propagates from seed; flowering in Apr/May; fruits in bunch; seeds are dispersed by birds.
33	Mainkada	*Xeromphis spinosa (Thunb.)*	Tree	Mostly in high land sal forests; flowers yellow.
37	Pangrang		Tree	In higher part of sal forests.
65	Jawali		Liana	Found in high land in sal forests.
99	MauriMataune jhar		Herb	Annual herb in plain.
117	Majheri		Herb	Found in damp area.
118	Panpate		Herb	Found in damp area.
122	Bichhad		Herb	Appears like tarul (93).
138	Furne		Fern	Not found in dry place; finger-like leaves.
167	Bhuikhari		Grass	Plentiful in sal forests.